COMPUTERIZED SONAR TRANSDUCER ANALYSIS AND DESIGN BASED ON MULTIPORT NETWORK INTERCONNECTION TECHNIQUES

by
H. H. Ding, L. E. McCleary, J. A. Ward
Sensor and Information Technology Department

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ROBERT H. GAUTIER, CAPT, USN
Commander

Wm. B. McLEAN, Ph.D.
Technical Director

ADMINISTRATIVE INFORMATION

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Released by
J. S. HICKMAN, Head
Transducer and Array
Systems Division

Under authority of
W. D. SQUIRE, Head
Sensor and Information Technology
Department

SUMMARY

PROBLEM

Develop a computer program to provide the capability for analysis and design of any conceivable electromechanical vibrator by implementing a generalized method based on multiport network interconnection techniques.

RESULTS

The computer program SEADUCER has been developed and applied successfully to several problems involving steady-state analysis and design of various longitudinal vibrators for Navy sonar systems. Calculations from mathematical models of transducer flexing heads have been curve-fit and then used in the program when vibrational modes other than plane wave have been known to exist. Applications other than longitudinal vibrator analysis have also been made successfully using the multiport interconnection techniques available in the program.

SEADUCER has been written so that it can easily be installed on most medium- to large-scale digital computers. The program is being used at other installations and is available to government and private organizations.

RECOMMENDATIONS

Develop a more general technique to solve for selected individual port variables. Also, implement hybrid interconnections to provide a more powerful tool. Additional mathematical models for element types should be added as the need arises. Applications to other fields such as electronics should be explored.

CONTENTS

INTRODUCTION

The purpose of this document is to provide a working guide to using the SEADUCER computer program. SEADUCER is an acronym for Steadystate Evaluation and Analysis of TransDUCERs. The techniques used by SEADUCER to combine sub-assemblies of transducers are applicable to math models for a wide variety of transducers. However, in this document SEADUCER is applied primarily to math models for longitudinal electromechanical vibrators. To a large extent, SEADUCER represents the state of the art both in the math models and in their computer implementation for analysis and design of this type of transducer. These computerized techniques have been developed and implemented by the Transducer and Array Systems Division, Code 601, of the Naval Undersea Center. SEADUCER, originally called MOD 8, is the latest in a long series of transducer analysis and design computer programs developed by NUC Code 601 and is significantly different in two respects:

(1) the mathematical method for combining the elements of the transducer is more flexible, and (2) the program implementation can be easily adapted for use on most medium- to large-scale digital computers.

For transducer analysis, SEADUCER has as its fundamental building blocks the mathematical models of transducer subassemblies. While some of these models have existed for years, their first combination into a transducer analysis computer program (MOD 1) was begun in 1961 by Dr. Gordon Martin of Code 601. Since that time several individuals have made a number of improvements in math models for sub-assemblies and in their use in transducer analysis programs.

The development of SEADUCER began early in 1968 when it became apparent that the existing MOD 7 program was not capable of handling several transducer configurations of importance. To overcome this problem, H. Ding and J. Ward of Code 601 described the method which forms the basis for combining elements in SEADUCER. This multiport interconnection technique is used primarily for transducer analysis and design; however, it can be used within the SEADUCER program for solution of other problems in electronics, mechanics, thermal flow, etc.

With the generalized multiport concepts available, L. McCleary began the computer implementation after appropriate computer input notation for the network interconnections was selected. The programming has proceeded continuously since that time.

The basic purpose of this report, as stated above, is to provide the potential user with enough information, including examples, to enable him to prepare typical transducer application computer runs. The mathematical equations used as a basis for the programs are given; but, in general, no derivation or detailed discussion of them is included, particularly if either is readily available in other literature.

The report consists of three major sections in addition to the Introduction. The first, Definitions and Conventions, presents the terms, definitions, and conventions used throughout the report. The second, Theoretical Description of Multiport Interconnection Technique, contains a mathematical description of the multiport interconnection technique. The third, General Description of Computer Program, presents the basic features of the SEADUCER Program for both programmers and non-programmers. There are six appendices, A through F. Appendix A is programmer oriented in that it provides a description of each subroutine in the program; the primary common storage blocks are also described. Appendix B defines the types of networks implemented, giving the input data required, sign conventions, and mathematical equations. Appendices C, D, and E present discussions and specific examples of computer runs for various applications involving longitudinal electromechanical vibrators. Appendix F, which is an active band-pass filter analysis, illustrates an application in a field other than transducer analysis. A complete computer program listing is too large to include in this report; however, copies of the program will be released in a form suitable for a particular installation on receipt by NUC Code 601 of an official request.

In order to make effective use of rapidly advancing technology, the SEADUCER program and documentation must be frequently updated. In order to accomplish this easily and efficiently, Appendix A had been completely computerized using a typesetting program so that future changes, deletions, and insertions can be made quickly and inexpensively. Such information will be supplied either as updates to this report or as follow-on reports when appropriate.

DEFINITIONS AND CONVENTIONS

The following definitions and explanatory notes are stated to aid clarity. Figure 1 illustrates many of the definitions given here. "Voltage" and "current" are used here but the same principles can be applied to a variety of problems, e.g., mechanical, in which case the preceding terms would be replaced by "force" and "velocity" respectively.

A *port* is defined as a terminal-pair wherein the current at one terminal must at every instant be equal and opposite to the current at the other terminal of the pair. An *accessible port* is a terminal-pair of a connected array of networks, whereas a *network port* is a terminal-pair of a single network.

A *multiport network* is defined as a set of linear equations relating current and voltage (or other analogous variables) at each of the one or more ports.

A *connection* must join together two or more network ports with a single accessible port. These ports are said to be *involved* in the connection.

A *series connection* is a connection wherein all involved ports have a common current; i.e., a *common-current loop* is formed by the connection.

A *parallel connection* is a connection wherein all involved ports have a common voltage; i.e., a *common-voltage node pair* is formed by the connection.

A connection involving no more than two network ports can be treated either as a series or parallel connection, depending on the type of accessible port involved.

A *series port* is a port involved in a series connection.

A *parallel port* is a port involved in a parallel connection.

An *interconnection* is defined as a connected array of a number of multiport networks containing at least one connection. An interconnection has one or more accessible ports and is itself a multiport network which relates current and voltage (or other analogous variables) at each of the one or more accessible ports.

A *series interconnection* is composed exclusively of series connections and is called Type S.

A *parallel interconnection* is composed exclusively of parallel connections and is called Type P.

A *hybrid* or *mixed interconnection* may contain both series and parallel connections.

Compaction is the process of removing undesired ports having trivial boundary conditions from an interconnection, leaving only those accessible ports desired in the final relationship. This is accomplished by placing the proper short- or open-circuit boundary condition on each undesired port. *Decompaction*, on the other hand, is the process of determining the voltages and currents at each port of every multiport network in the interconnection, subject to the necessary and sufficient boundary conditions applied to the accessible ports of the interconnection.

Several different matrix forms are used in describing multiport networks. The Z-form relates voltage to current, i.e.,

$$[E] = [Z][I]$$

where [E] is the voltage vector, [Z] is impedance matrix, and [I] is the current vector. The Y-form relates current to voltage, or

$$[I] = [Y][E],$$

where [I] and [E] are vectors as before, and [Y] is the admittance matrix. Another useful form which is defined for even-order networks only is the A-form, which maps output port variables into the input port variables, i.e., for a two-port network,

$$\begin{bmatrix} E_i \\ I_i \end{bmatrix} = [A] \begin{bmatrix} E_o \\ I_o \end{bmatrix} .$$

The naming convention adopted for network ports is

± ± i X n Yk

where

i is the port number (arbitrarily numbered from 1,...,n for each network),

X and Y are any pair of letters used to uniquely name the network or interconnection,

n is the number of ports possessed by network XnY, and

k is the piece number (used only for certain types of networks which allow automatic cascading of pieces with the same name – normally 2 × 2 matrices in the A-form).

Note: A *section* is either an input network which has no piece numbers or a network which is composed of cascaded pieces.

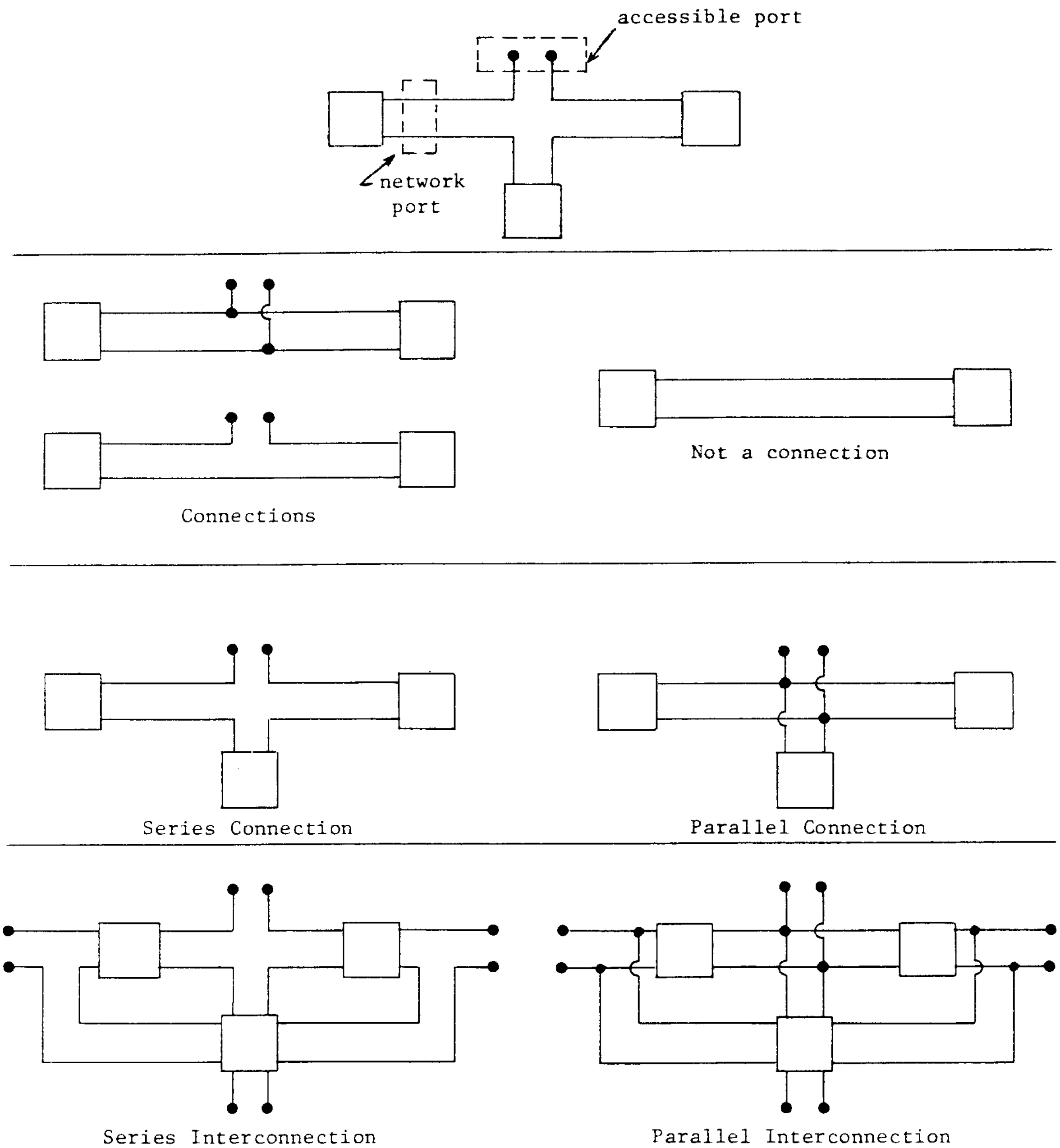


Figure 1. Illustration of Definitions. In many cases an accessible port is introduced artificially in order to satisfy the definition of a connection and then is later terminated with a trivial boundary condition (opened or shorted).

The signs preceding the name are used to define the sign convention prescribed by the user and represent the sign of the dependent variable (or force, for series) and independent variable (or velocity, for series), respectively. For examply, consider the network, A2B, shown in figure 2. The first accessible port is 1A2B, and the second is 2A2B. The connection joins two pieces, A2B1 and A2B2.

Several different network sign conventions may be used simultaneously with an interconnection provided that the sign convention ascribed to a given network is consistent with the given network equations.

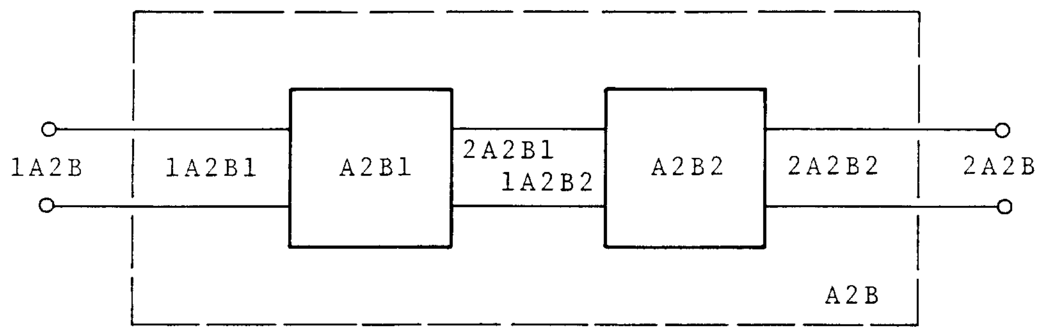


Figure 2. Network Illustrating Naming Convention.

THEORETICAL DESCRIPTION OF MULTIPORT INTERCONNECTION TECHNIQUE

The technique described in this section is simply a transformation of variables process. The voltages and currents at each network port (old variables) are transformed into the voltages and currents at each accessible port (new variables) by means of two transformation matrices determined by the interconnection topology and by Kirchoff's laws. The determination of these two transformation matrices and subsequent operations are much simpler if the appropriate connection definition (series or parallel) is used wherever there is a choice.

The following development assumes a hybrid or mixed form of interconnection for generality. Consider the b^{th} interconnection of N multiport networks where each network has p_n ports (n=1,2,...,r,...,N). Each network may be written in the following form relating *network port* variables:

$$[W_i^r] = [K_{ij}^r]\,[U_j^r] \qquad (i,j=1,2,3,\ldots,p_r),$$

where $[W_i^r]$ and $[U_j^r]$ are column vectors of p_r components, $[K_{ij}^r]$ is a square matrix of $p_r \times p_r$ components, and W_a^r and U_a^r are the two port variables at the a^{th} port of the r^{th} network.

Proper formulation of $[W_i^r]$ and $[U_j^r]$ implies the following conditions for the r^{th} network:

if 'a' is a series network port, $W_a^r = E_a^r$ and $U_a^r = I_a^r$;

if 'a' is a parallel network port, $W_a^r = I_a^r$ and $U_a^r = E_a^r$.

where E denotes port voltage and I denotes port current.

These "proper formulation" rules are required to allow an automatic application of short- and open-circuit boundary conditions to undesired accessible ports during the *compaction* process.

Since each network matrix equation is independent of the interconnection, the entire set of interconnected multiport networks may be arrayed in a single matrix equation, once the individual network equations are in proper form.

$$\begin{bmatrix} (W_i^1) \\ (W_i^2) \\ \cdot \\ \cdot \\ \cdot \\ (W_i^N) \end{bmatrix} = \begin{bmatrix} (K_{ij}^1) & (0) & \dots & (0) \\ (0) & (K_{ij}^2) & \dots & (0) \\ \cdot & \cdot & \dots & \cdot \\ \cdot & \cdot & \dots & \cdot \\ \cdot & \cdot & \dots & \cdot \\ (0) & (0) & \dots & (K_{ij}^N) \end{bmatrix} \begin{bmatrix} (U_j^1) \\ (U_j^2) \\ \cdot \\ \cdot \\ \cdot \\ (U_j^N) \end{bmatrix} \quad (i,j=1,2,\dots,p_n),$$

or, expressed simply, $[W_i^n] = [K_{ij}^n][U_j^n]$ $(n=1,2,\dots,N)(i,j=1,2,\dots,p_n)$, where $[W_i^n]$ and $[U_j^n]$ are column vectors of $\sum_{n=1}^{N} p_n$ components (each a voltage or current) and $[K_{ij}^n]$ is a square matrix of $\sum_{n=1}^{N} p_n \times \sum_{n=1}^{N} p_n$ components.

Consider the relationship of *accessible port* variables for the b^{th} interconnection (p_b in number):

$$[W_k^b] = [K_{k\ell}^b]\,[U_\ell^b] \qquad (k,\ell=1,2,\dots,p_b),$$

where $[W_k^b]$ and $[U_\ell^b]$ are column vectors of p_b components, each a voltage or current, and $[K_{k\ell}^b]$ is a $p_b \times p_b$ square matrix.

From previous definitions and conventions, the p_b accessible ports include, at a minimum, a series accessible port in every series connection, a parallel accessible port in every parallel connection, and an unaffected accessible port for every unaffected network port (which may be specified as either series or parallel connection). If additional accessible ports are introduced, they will lead, at best, to formation of hybrid connections necessitating further work.

Again, proper formulation of $[W_k^b]$ and $[U_\ell^b]$ implies that

if a is a series port, $W_a^b = E_a^b$ and $U_a^b = I_a^b$;

if a is a parallel port, $W_a^b = I_a^b$ and $U_a^b = E_a^b$,

where E denotes port voltage and I denotes port current.

In general (for the hybrid or mixed interconnection), the W and U matrices contain both E and I elements mixed according to the occurrence of series and parallel connections and unaffected ports in the hybrid interconnection. If all connections are series or all connections are parallel, the W and U matrices will not be mixed.

The transformation matrices are defined as follows:

$$[W_k^b] \overset{D}{=} [C^b]\ [W_i^n] \qquad \text{(subscripts as before)}$$

$$[U_j^n] \overset{D}{=} [D^b]\ [U_\ell^b]$$

$$[W_k^b] = [C^b][W_i^n] = [C^b][K_{ij}^n][U_j^n] = [C^b][K_{ij}^n][D^b][U_\ell^b]$$

which implies

$$[K_{k\ell}^b] = [C^b][K_{ij}^n][D^b].$$

The $[C^b]$ and $[D^b]$ *connection* or *transformation* matrices are determined by applying Kirchoff's laws to the interconnection topology and will contain only integer elements equal to zero or ± 1. $[C^b]$ has p_b rows and $\sum_{n=1}^{N} p_n$ columns, and $[D^b]$ has $\sum_{n=1}^{N} p_n$ rows and p_b columns.

If there exists a connection between two or more network ports without at least one involved accessible port (contrary to definition), a row or column of the $[C^b]$ and $[D^b]$ matrices will contain all zeros and will cause an invalid variable transformation.

Consider the matrix equation for all accessible ports for the b^{th} interconnection following transformation of variables:

$$[W_k^b] = [K_{k\ell}^b][U_\ell^b] \qquad (k,\ell=1,2,\ldots,p_b).$$

Many of the accessible ports present during transformation of variables may have trivial boundary conditions (i.e., open- or short-circuit) and this may not be desired in the final relationship. *Compaction* of the interconnection is accomplished as follows:

Let

α = number of desired accessible ports,

β = number of undesired accessible ports (to be shorted if series and opened if parallel in form).

Therefore,

$$p_b = \alpha + \beta.$$

The matrix equation after transformation of variables must be partitioned (by the method described later in this section). The rearranged and partitioned equation may be written as (dropping the interconnection-naming superscript, "b")

$$\begin{bmatrix} [W_a] \\ [W_b] \end{bmatrix} = \begin{bmatrix} [K_{ac}] & [K_{ad}] \\ [K_{bc}] & [K_{bd}] \end{bmatrix} \begin{bmatrix} [U_c] \\ [U_d] \end{bmatrix} \qquad \begin{matrix} (a,c=1,2,\ldots,\alpha) \\ (b,d=1,2,\ldots\beta). \end{matrix}$$

The undesired ports may be removed by setting $[W_b] = [0]$. This effectively shorts a series port ($E \to 0$) and opens a parallel port ($I \to 0$) which generally represents the trivial boundary conditions. Therefore, setting $[W_b] = [0]$ and rearranging terms, we find that

$$[U_d] = -[K_{bd}]^{-1} [K_{bc}] [U_c].$$

So

$$[W_a] = \left[[K_{ac}] - [K_{ad}] [K_{bd}]^{-1} [K_{bc}] \right] [U_c],$$

or

$$[W_a] = [H_{ac}] [U_c],$$

where

$$[H_{ac}] = [K_{ac}] - [K_{ad}] [K_{bd}]^{-1} [K_{bc}].$$

This is the generalized compacted interconnection equation relating voltages and currents (or analogous quantities) at the α desired accessible ports of the N interconnected multiport networks.

To illustrate the decompaction process, consider the generalized *compacted* interconnection equation for the b^{th} interconnection:

$$[W_a^b] = [H_{ac}^b] [U_c^b] \qquad (a,c=1,2,\ldots,\alpha).$$

The applied boundary conditions are such that $[U_c]$ can be evaluated as a function of the known terminating impedances, voltages, and currents, i.e.,

(It is necessary and sufficient that α independent boundary conditions be specified.)

$$[U_c^b] = f(W, W/U, U),$$

where W, W/U, and U are the necessary boundary conditions at the accessible ports of the compacted interconnection. From the previous development of the compacted interconnection equation, $[U_d]$ may be computed:

$$[U_d^b] = -[K_{bd}^b]^{-1}[K_{bc}^b]\ [U_c^b] \qquad \begin{matrix}(a,c=1,2,\ldots,\alpha)\\ (b,d=1,2,\ldots,\beta).\end{matrix}$$

So, $[U_\ell^b]$ may be computed:

$$[U_\ell^b] = \begin{bmatrix} U_c^b \\ \\ U_d^b \end{bmatrix} \qquad (\ell=1,2,\ldots,p_b).$$

Also, $[U_j^n]$ may be computed:

$$[U_j^n] = [D^b]\ [U_\ell^b].$$

Decompaction allows computation of all network port variables, subject to boundary conditions, as follows:

$$[U_j^n] = [D^b] \begin{bmatrix} [U_c^b] \\ \\ [-[K_{bd}^b]^{-1}\ [K_{bc}^b]\ [U_c^b]] \end{bmatrix} \qquad \text{(Subscripts as before)}$$

$$[W_j^n] = [K_{ij}^n]\ [U_j^n].$$

PARTITIONING METHOD

A *partitioning method* for rearrangement of variables can be used to convert any network equation into a more desirable form than might occur as a matter of course. Consider the following:

$$[W_\alpha^b] = [K_{\alpha\gamma}^b]\ [U_\gamma^b] \qquad (\alpha,\gamma=1,2,\ldots,p_b),$$

or simply,

$$[W] = [K]\ [U].$$

Where certain elements of [W] are voltages (at series ports) and others are currents (at parallel ports). Rearrangement and partitioning yields

$$\begin{bmatrix} [W_s] \\ [W_p] \end{bmatrix} \quad \begin{bmatrix} [H_1] & [H_2] \\ [H_3] & [H_4] \end{bmatrix} \quad \begin{bmatrix} [U_s] \\ [U_p] \end{bmatrix}.$$

where

$[W_s]$ and $[U_s]$ exist at series ports

and

$[U_p]$ and $[W_p]$ exist at parallel ports.

i.e., the series port variables and parallel port variables have been grouped in each of the vectors. Although similar manipulation will produce various forms of this matrix equation, the relationship in the Z-form,

$$\begin{bmatrix} [W_s] \\ [U_p] \end{bmatrix} = \begin{bmatrix} [Z_1] & [Z_2] \\ [Z_3] & [Z_4] \end{bmatrix} \quad \begin{bmatrix} [U_s] \\ [W_p] \end{bmatrix},$$

or

$$[E] = [Z]\,[I],$$

is found by solving

$$[W_s] = [H_1]\,[U_s] + [H_2]\,[U_p]$$

$$[W_p] = [H_3]\,[U_s] + [H_4]\,[U_p]$$

for

$$[U_p] = [H_4]^{-1}\,[W_p] - [H_4]^{-1}\,[H_3]\,[U_s].$$

We find that

$$[W_s] = [H_2]\,[H_4]^{-1}\,[W_p] + \Big[[H_1] - [H_2]\,[H_4]^{-1}\,[H_3]\Big]\,[U_s].$$

Therefore,

$$[Z] = \begin{bmatrix} \big[[H_1] - [H_2]\,[H_4]^{-1}\,[H_3]\big] & [H_2]\,[H_4]^{-1} \\ -\,[H_4]^{-1}\,[H_3] & [H_4]^{-1} \end{bmatrix}.$$

The resultant Z-form relates the voltages at the network ports to the currents at the network ports.

In general, this partitioning method is used in converting individual multiport equations into required form, and is used in compaction. Also, if it is necessary to short a parallel port ($E \rightarrow 0$) or open a series port ($I \rightarrow 0$), this method can be used prior to compaction to arrange the elements of [W] appropriately. Finally, in setting boundary conditions, this method is used to solve for $[U_c]$ from the actual boundary conditions applied to the desired accessible ports.

The current computer program will not handle hybrid interconnections (i.e., mixtures of series and parallel interconnections); therefore, only two types of interconnections will be discussed.

Type S

This interconnection is composed exclusively of series connections. Type S requires the use of a Z-form description of the individual networks, which is a common form for network description. This type occurs most frequently in transducer models. Figure 3 shows an example of a series interconnection of three multiport networks having two desired accessible ports where loop 4 involves only two network ports and, therefore, may be treated as either a parallel or series connection. Figure 4 shows the interconnection with all four accessible ports, one being the unaffected network port and one involved in each of the three series connections.

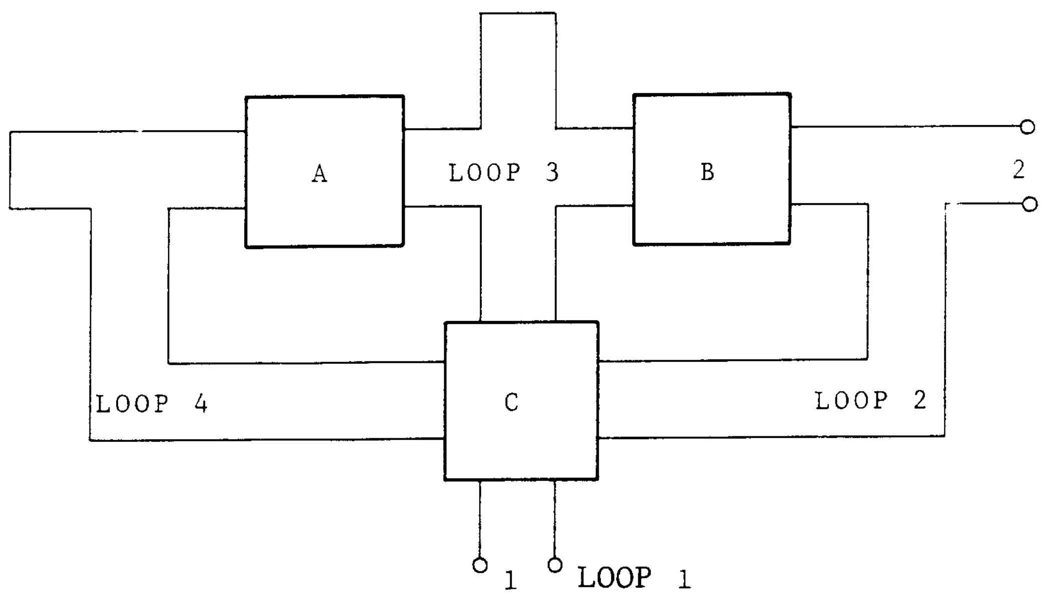


Figure 3. Series Interconnection.

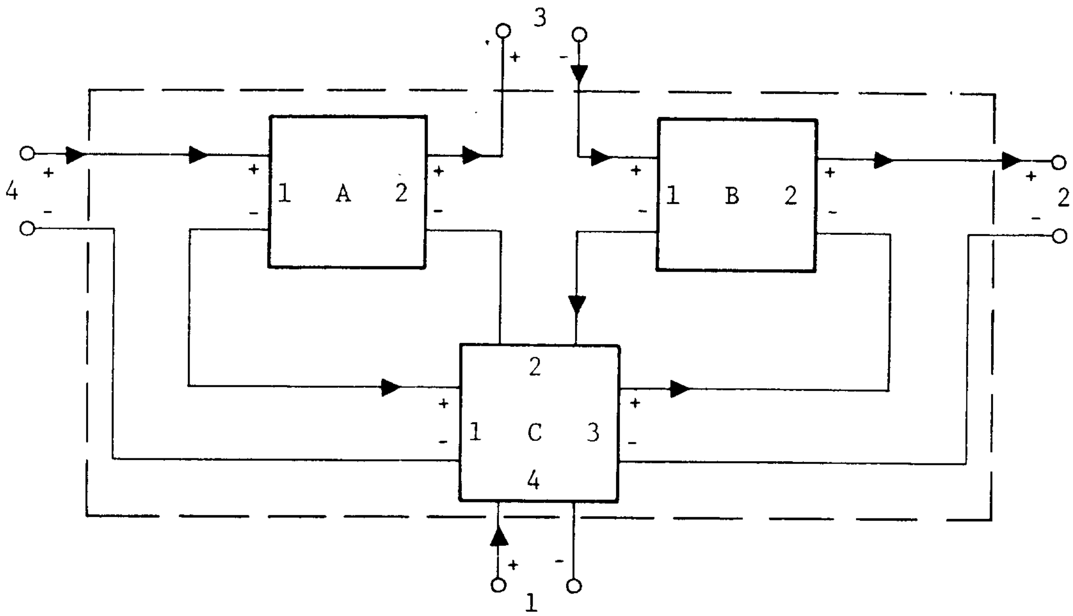


Figure 4. Series Interconnection With Sign Convention.

The following equations describe each of the networks shown in the figure:

$$\begin{bmatrix} E_1^A \\ E_2^A \end{bmatrix} = \begin{bmatrix} Z_{11}^A & Z_{12}^A \\ Z_{21}^A & Z_{22}^A \end{bmatrix} \begin{bmatrix} I_1^A \\ I_2^A \end{bmatrix},$$

$$\begin{bmatrix} E_1^B \\ E_2^B \end{bmatrix} = \begin{bmatrix} Z_{11}^B & Z_{12}^B \\ Z_{21}^B & Z_{22}^B \end{bmatrix} \begin{bmatrix} I_1^B \\ I_2^B \end{bmatrix}.$$

$$\begin{bmatrix} E_1^C \\ E_2^C \\ E_3^C \\ E_4^C \end{bmatrix} = \begin{bmatrix} Z_{11}^C & Z_{12}^C & Z_{13}^C & Z_{14}^C \\ Z_{21}^C & Z_{22}^C & Z_{23}^C & Z_{24}^C \\ Z_{31}^C & Z_{32}^C & Z_{33}^C & Z_{34}^C \\ Z_{41}^C & Z_{42}^C & Z_{43}^C & Z_{44}^C \end{bmatrix} \begin{bmatrix} I_1^C \\ I_2^C \\ I_3^C \\ I_4^C \end{bmatrix}$$

The Z-form was chosen since every port involved in the connection is a series port and the description of the ports should therefore use current as the independent variable, i.e.,

$$[W_i^n] = [E_i^n].$$

$$[U_j^n] = [I_j^n].$$

The entire set of network equations can be written

$$[W_i^n] = [K_{ij}^n]\ [U_j^n] \qquad (n=A,B,C),$$

or

$$[E_i^n] = [Z_{ij}^n]\ [I_j^n] \qquad \text{(for series ports).}$$

Thus,

$$\begin{bmatrix} E_1^A \\ E_2^A \\ E_1^B \\ E_2^B \\ E_1^C \\ E_2^C \\ E_3^C \\ E_4^C \end{bmatrix} = \begin{bmatrix} Z_{11}^A & Z_{12}^A & 0 & 0 & 0 & 0 & 0 & 0 \\ Z_{21}^A & Z_{22}^A & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & Z_{11}^B & Z_{12}^B & 0 & 0 & 0 & 0 \\ 0 & 0 & Z_{21}^B & Z_{22}^B & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & Z_{11}^C & Z_{12}^C & Z_{13}^C & Z_{14}^C \\ 0 & 0 & 0 & 0 & Z_{21}^C & Z_{22}^C & Z_{23}^C & Z_{24}^C \\ 0 & 0 & 0 & 0 & Z_{31}^C & Z_{32}^C & Z_{33}^C & Z_{34}^C \\ 0 & 0 & 0 & 0 & Z_{41}^C & Z_{42}^C & Z_{43}^C & Z_{44}^C \end{bmatrix} \begin{bmatrix} I_1^A \\ I_2^A \\ I_1^B \\ I_2^B \\ I_1^C \\ I_2^C \\ I_3^C \\ I_4^C \end{bmatrix}.$$

Next, we write the relationships between voltages and currents at the four accessible ports of the interconnection (naming it "D"):

$$[W_k^D] = [K_{k\ell}^D]\ [U_\ell^D] \qquad (k,\ell = 1,2,3,4).$$

Since all four accessible ports are series ports,

$$[W_k^D] = [E_k^D],$$

$$[U_\ell^D] = [I_\ell^D],$$

and

$$\begin{bmatrix} E_1^D \\ E_2^D \\ E_3^D \\ E_4^D \end{bmatrix} = [Z_{k\ell}^D] \begin{bmatrix} I_1^D \\ I_2^D \\ I_3^D \\ I_4^D \end{bmatrix} .$$

The transformation of variables is accomplished by means of the $[C^D]$ and $[D^D]$ matrices, which can be determined by inspection of figure 4 (for sign conventions, etc.) and by referral to Kirchoff's laws.

$$\begin{bmatrix} E_1^D \\ E_2^D \\ E_3^D \\ E_4^D \end{bmatrix} = [C^D] \begin{bmatrix} E_1^A \\ E_2^A \\ E_1^B \\ E_2^B \\ E_1^C \\ E_2^C \\ E_3^C \\ E_4^C \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 1 & -1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} E_1^A \\ E_2^A \\ E_1^B \\ E_2^B \\ E_1^C \\ E_2^C \\ E_3^C \\ E_4^C \end{bmatrix} ,$$

or

$$\begin{aligned} E_1^D &= E_4^C \\ E_2^D &= E_2^B + E_3^C \\ E_3^D &= E_2^A + E_2^C - E_1^B \\ E_4^D &= E_1^A + E_1^C \end{aligned}$$

$$
\begin{bmatrix} I_1^A \\ I_2^A \\ I_1^B \\ I_2^B \\ I_1^C \\ I_2^C \\ I_3^C \\ I_4^C \end{bmatrix} = [D^D] \begin{bmatrix} I_1^D \\ I_2^D \\ I_3^D \\ I_4^D \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} I_1^D \\ I_2^D \\ I_3^D \\ I_4^D \end{bmatrix}
$$

or

$$
\begin{aligned}
I_1^D &= I_4^C \\
I_2^D &= I_2^B = I_3^C \\
I_3^D &= I_2^A = I_1^B = I_2^C \\
I_4^D &= I_1^A = I_1^C .
\end{aligned}
$$

Finally, using the expression from the general description

$$[K_{k\ell}^D] = [C^D]\ [K_{ij}^n]\ [D^D],$$

we find that

$$[K^D_{k\ell}] = \begin{bmatrix} 0&0&0&0&0&0&0&1 \\ 0&0&0&1&0&0&1&0 \\ 0&1&-1&0&0&1&0&0 \\ 1&0&0&0&1&0&0&0 \end{bmatrix} \begin{bmatrix} Z^A_{11} & Z^A_{12} & 0&0&0&0&0&0 \\ Z^A_{21} & Z^A_{22} & 0&0&0&0&0&0 \\ 0&0& Z^B_{11} & Z^B_{12} & 0&0&0&0 \\ 0&0& Z^B_{21} & Z^B_{22} & 0&0&0&0 \\ 0&0&0&0& Z^C_{11} & Z^C_{12} & Z^C_{13} & Z^C_{14} \\ 0&0&0&0& Z^C_{21} & Z^C_{22} & Z^C_{23} & Z^C_{24} \\ 0&0&0&0& Z^C_{31} & Z^C_{32} & Z^C_{33} & Z^C_{34} \\ 0&0&0&0& Z^C_{41} & Z^C_{42} & Z^C_{43} & Z^C_{44} \end{bmatrix} \begin{bmatrix} 0&0&0&1 \\ 0&0&1&0 \\ 0&0&1&0 \\ 0&1&0&0 \\ 0&0&0&1 \\ 0&0&1&0 \\ 0&1&0&0 \\ 1&0&0&0 \end{bmatrix}$$

or

$$[K^D_{k\ell}] = \begin{bmatrix} Z^C_{44} & Z^C_{43} & Z^C_{42} & Z^C_{41} \\ Z^C_{34} & (Z^C_{33} + Z^B_{22}) & (Z^C_{32} + Z^B_{21}) & Z^C_{31} \\ Z^C_{24} & (Z^C_{23} - Z^B_{12}) & (Z^C_{22} + Z^A_{22} - Z^B_{11}) & (Z^C_{21} + Z^A_{21}) \\ Z^C_{14} & Z^C_{13} & (Z^C_{12} + Z^A_{12}) & (Z^C_{11} + Z^A_{11}) \end{bmatrix} .$$

Since the boundary conditions at accessible ports 3 and 4 are trivial short circuits, the matrix may be compacted. This compaction will not be done in detail but will be sketched as follows (no rearrangement is necessary in this instance):

$$\left[\begin{array}{c} E^D_1 \\ E^D_2 \\ \hline E^D_3 \\ E^D_4 \end{array}\right] = \left[\begin{array}{cc|cc} Z^C_{44} & Z^C_{43} & Z^C_{42} & Z^C_{41} \\ Z^C_{34} & (Z^C_{33} + Z^B_{22}) & (Z^C_{32} + Z^B_{21}) & Z^C_{31} \\ \hline Z^C_{24} & (Z^C_{23} - Z^B_{12}) & (Z^C_{22} + Z^A_{22} - Z^B_{11}) & (Z^C_{21} + Z^A_{21}) \\ Z^C_{14} & Z^C_{13} & (Z^C_{12} + Z^A_{12}) & (Z^C_{11} + Z^A_{11}) \end{array}\right] \begin{bmatrix} I^D_1 \\ I^D_2 \\ I^D_3 \\ I^D_4 \end{bmatrix} = \begin{bmatrix} E^D_a \\ \\ E^D_b \\ \\ \end{bmatrix}$$

Recall that if

$$\begin{bmatrix} [W_a] \\ [W_b] \end{bmatrix} = \begin{bmatrix} [K_{ac}] & [K_{ad}] \\ [K_{bc}] & [K_{bd}] \end{bmatrix} \begin{bmatrix} [U_c] \\ [U_d] \end{bmatrix} \qquad \begin{array}{l} a,c \rightleftarrows \text{desired} \\ b,d \rightleftarrows \text{undesired}, \end{array}$$

and

$$[W_b] = 0$$

then

$$[W_a] = \Big[[K_{ac}] - [K_{ad}][K_{bd}]^{-1}[K_{bc}]\Big] \; [U_c] = [H^D][U_c].$$

Therefore,

$$\begin{bmatrix} H^D_{11} & H^D_{12} \\ H^D_{21} & H^D_{22} \end{bmatrix} = \begin{bmatrix} (Z^C_{44}) & (Z^C_{43}) \\ (Z^C_{34}) & (Z^C_{33} + Z^B_{22}) \end{bmatrix} - \begin{bmatrix} (Z^C_{42}) & (Z^C_{41}) \\ (Z^C_{32} + Z^B_{21}) & (Z^C_{31}) \end{bmatrix}$$

$$\times \begin{bmatrix} (Z^C_{22} + Z^A_{22} - Z^B_{11}) & (Z^C_{21} + Z^A_{21}) \\ (Z^C_{12} + Z^A_{12}) & (Z^C_{11} + Z^A_{11}) \end{bmatrix}^{-1} \times \begin{bmatrix} Z^C_{24} & (Z^C_{23} - Z^B_{12}) \\ Z^C_{14} & Z^C_{13} \end{bmatrix},$$

which will yield through simple matrix multiplication and addition a final result in the form

$$\begin{bmatrix} E^D_1 \\ E^D_2 \end{bmatrix} = \begin{bmatrix} H^D_{11} & H^D_{12} \\ H^D_{21} & H^D_{22} \end{bmatrix} \begin{bmatrix} I^D_1 \\ I^D_2 \end{bmatrix},$$

where the elements of the H-matrix are known in terms of the elements of the Z-matrices for the three networks which were given originally.

Type P

This interconnection is composed exclusively of parallel connections. The example is included here to illustrate that connections involving only two network ports may be treated either as series or parallel. Consider the same three networks used in the Type S example, but connected in parallel as shown in figure 5. Node-pair 4 is introduced instead of Loop 4 as before, and is treated as a parallel connection here. The Y-form will be used for this interconnection, since every port involved is a parallel port. In view of the requirements of proper formulation discussed previously, voltage must be the independent variable. Thus,

$$[W^n_i] = [I^n_i]$$

$$[U^n_j] = [E^n_j] \qquad \text{(for parallel ports).}$$

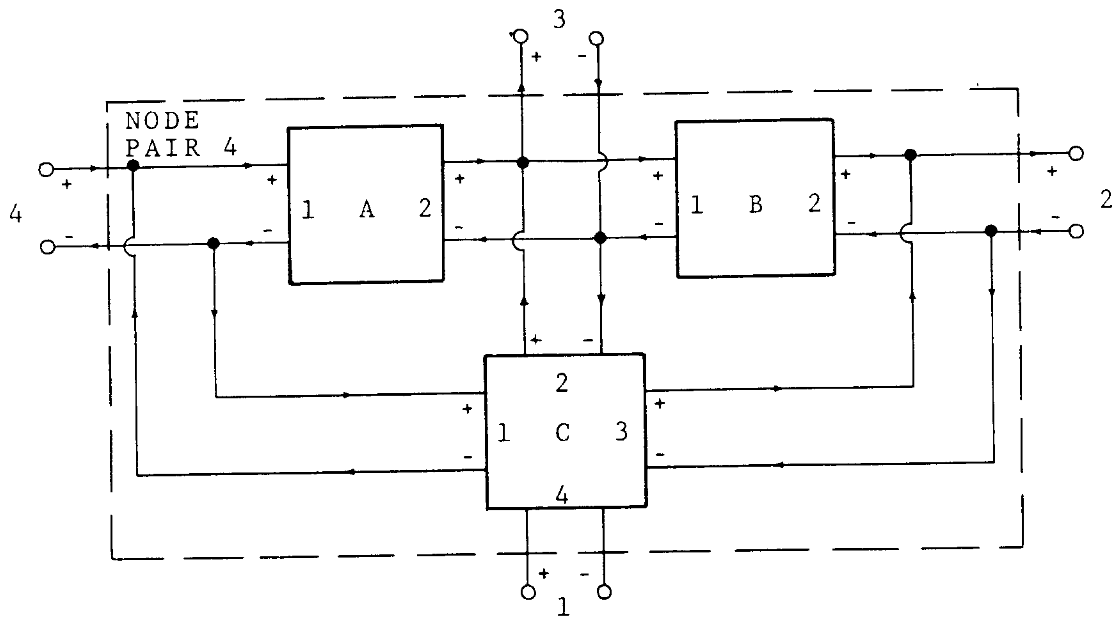


Figure 5. Parallel Interconnection.

If the Z-form is known for each network, the following conversion from the Z-form to the Y-form is required:

We know that $[E] = [Z]\ [I]$,

$$[I] = [Z]^{-1}[E].$$

and

$$[I] = [Y]\ [E].$$

Therefore,

$$[Y] = [Z]^{-1}.$$

In particular, for A, B, and C,

$$[I^A] = [Y^A]\ [E^A],\ \text{where } [Y^A] = [Z^A]^{-1};$$

$$[I^B] = [Y^B]\ [E^B],\ \text{where } [Y^B] = [Z^B]^{-1};$$

and

$$[I^C] = [Y^C]\ [E^C],\ \text{where } [Y^C] = [Z^C]^{-1}.$$

It should be noted that the unaffected port can also be considered as a series port, as is done for Type S interconnection, in which case the matrix equation for network C would take the following hybrid K-form (not yet implemented in the computer program package):

$$\begin{bmatrix} I_1^C \\ I_2^C \\ I_3^C \\ E_4^C \end{bmatrix} = \begin{bmatrix} K_{11}^C & K_{12}^C & K_{13}^C & K_{14}^C \\ K_{21}^C & K_{22}^C & K_{23}^C & K_{24}^C \\ K_{31}^C & K_{32}^C & K_{33}^C & K_{34}^C \\ K_{41}^C & K_{42}^C & K_{43}^C & K_{44}^C \end{bmatrix} \begin{bmatrix} E_1^C \\ E_2^C \\ E_3^C \\ I_4^C \end{bmatrix},$$

where $[K^C]$ is determined from $[Z^C]$ by means of the partitioning method discussed previously. However, this unaffected network port is treated as a parallel port in this example to simplify the problem and to allow the use of the simpler Y-form notation.

The entire set of network equations can be written as

$$\begin{bmatrix} I_1^A \\ I_2^A \\ I_1^B \\ I_2^B \\ I_1^C \\ I_2^C \\ I_3^C \\ I_4^C \end{bmatrix} = \begin{bmatrix} Y_{11}^A & Y_{12}^A & 0 & 0 & 0 & 0 & 0 & 0 \\ Y_{21}^A & Y_{22}^A & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & Y_{11}^B & Y_{12}^B & 0 & 0 & 0 & 0 \\ 0 & 0 & Y_{21}^B & Y_{22}^B & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & Y_{11}^C & Y_{12}^C & Y_{13}^C & Y_{14}^C \\ 0 & 0 & 0 & 0 & Y_{21}^C & Y_{22}^C & Y_{23}^C & Y_{24}^C \\ 0 & 0 & 0 & 0 & Y_{31}^C & Y_{32}^C & Y_{33}^C & Y_{34}^C \\ 0 & 0 & 0 & 0 & Y_{41}^C & Y_{42}^C & Y_{43}^C & Y_{44}^C \end{bmatrix} \begin{bmatrix} E_1^A \\ E_2^A \\ E_1^B \\ E_2^B \\ E_1^C \\ E_2^C \\ E_3^C \\ E_4^C \end{bmatrix}.$$

Again, if we name the interconnection "Network #D", the relationship between the voltages and currents at the four accessible ports is described by the following equations:

$$[W_k^D] = [K_{k\ell}^D]\ [U_\ell^D] \qquad (k,\ell = 1,2,3,4),$$

where

$$[W_k^D] = [I_k^D],$$

$$[U_\ell^D] = [E_\ell^D],$$

and $$[K_{k\ell}^D] = [Y_{k\ell}^D].$$

Thus, $$[I_k^D] = [Y_{k\ell}^D]\,[E_\ell^D].$$

The transformation of variables is again accomplished by means of the $[C^D]$ and $[D^D]$ matrices, which are determined from the diagram and Kirchoff's laws.

$$[I_k^D] = [C^D]\,[I_i^n];\quad [E_j^n] = [D^D]\,[E_\ell^D]$$

$$[C^D] = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 1 & -1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \end{bmatrix} \qquad \begin{aligned} I_1^D &= I_4^C \\ I_2^D &= I_2^B + I_3^C \\ I_3^D &= I_2^A + I_2^C - I_1^B \\ I_4^D &= I_1^A - I_1^C \end{aligned}$$

$$[D^D] = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & -1 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \qquad \begin{aligned} E_1^D &= E_4^C \\ E_2^D &= E_2^B = E_3^C \\ E_3^D &= E_2^A = E_1^B = E_2^C \\ E_4^D &= E_1^A = -E_1^C \end{aligned}$$

Finally,

$$[Y^D_{k\ell}] = [C^D][Y^n_{ij}][D^D];$$

$$[Y^D_{k\ell}] = \begin{bmatrix} Y^C_{44} & Y^C_{43} & Y^C_{42} & -Y^C_{41} \\ Y^C_{34} & (Y^C_{33}+Y^B_{22}) & (Y^C_{32}+Y^B_{21}) & -Y^C_{31} \\ Y^C_{24} & (Y^C_{23}-Y^B_{12}) & (Y^C_{22}+Y^A_{22}-Y^B_{11}) & (Y^A_{21}-Y^C_{21}) \\ -Y^C_{14} & -Y^C_{13} & (-Y^C_{12}+Y^A_{12}) & (Y^A_{11}+Y^C_{11}) \end{bmatrix}.$$

Since ports 3 and 4 are trivially open circuited, the matrix equation can again be compacted to yield this expression:

$$\begin{bmatrix} I^D_1 \\ I^D_2 \end{bmatrix} = [H^D] \begin{bmatrix} E^D_1 \\ E^D_2 \end{bmatrix},$$

where $[H^D]$ is now in the Y-form.

The fact that only series and parallel interconnections are considered here should not be construed by the reader to mean that the theoretical methods presented are restricted to these types of connections. The theory is general and valid for hybrid interconnections; however, the computer program will, at present, handle only series interconnections or parallel interconnections.

GENERAL DESCRIPTION OF COMPUTER PROGRAM

The purpose of this section is to provide insight into the basic features of the computer program for both programmers and non-programmers. The description is organized into the following sections:

(1) SEADUCER Computer Programming Considerations,

(2) Network Types,

(3) Interconnection Table,

(4) Catalog,

(5) Boundary Condition Specification,

(6) Control Program,

(7) Program Conversion from Double Precision to Single Precision, and

(8) Summary.

SEADUCER COMPUTER PROGRAMMING CONSIDERATIONS

Basic design goals for the programming of SEADUCER are as follows:

1. Provide for computerized analysis and design of transducers based on multiport network interconnection techniques.
2. Produce the program in a form as near standard as possible so that it can easily be implemented on most medium- to large-scale digital computers.
3. Provide for automatic run-by-run allocation of the core storage required for storing all input data as well as computed variables and matrices for any transducer configuration.
4. Provide an extremely straightforward method for converting the program from double precision to single precision.
5. Allow for complete program flexibility by requiring for each application the preparation of a main routine, written in the programming language, which explicitly controls the flow of input, computation, and output.
6. Provide for output options to be controlled independently of computations performed. These options are for printout as well as output via tape or cards to be processed with a separate plotting package.

In order to implement these basic goals, the following measures have been taken:

1. Even though the multiport technique has been implemented primarily for transducer applications, a great deal of care has been taken to allow the implementation of other applications.
2. ASA FORTRAN has been followed as faithfully as possible throughout the body of the program. The primary exception is the use of the FLD function, which must be provided for bit handling.
3. By setting Blank Common to an appropriate size within the main routine, the user is able to set aside only as much core storage as is required for a particular run. This is especially advantageous when using computer systems which charge for the amount of core used. It also eliminates the problem of dimensioning large areas of core that are not used in all applications.
4. The primary mode of the program is double precision. However, a consistent convention has been used throughout the program making it simple to create a single precision version. This allows an installation to maintain both single and double precision versions, if necessary. Where 20 to 23 bits of precision are available in single precision, many applications will require double; while for 48 bits in single precision, it is unlikely that double would be required. Further analysis of the various precisions available will need to be performed for particular applications.

5. Since no package of application-oriented subroutines can ever contain every conceivable option and variation required in a fast-moving research and development environment, SEADUCER requires that for each application a FORTRAN main routine be written (referred to as the Control Routine). For the typical transducer application such as that described in Appendix C, the Control Routine involves several subroutine calls to load the network configuration, several subroutine calls to load the input data, and several calls for the desired logic and output. Only in cases where a large volume of repetitive data is required are actual data cards read in for input parameters. In general, it is desirable to have the input data loaded within the main routine since only in this way can values be directly computed as they are loaded into the program. This method also allows complete flexibility with respect to the order and number of input combinations without having to settle for options preset within the program.

   The success of this approach depends upon having a method for the particular computer system which allows the storage (preferably in source and relocatable code) of the entire program on magnetic tape (or disk, drum, etc.). This storage must be in a form such that for a particular run, the user need only keypunch the Control Routine and system control cards required for automatically compiling the Control Routine as well as loading and executing the desired portion of the program. Here is where sophisticated computer system loaders are highly desirable, since they can be used to load only the sections of SEADUCER needed for a particular run. Presently, the entire program cannot be loaded into a 32K word machine at one time, although with proper selective loading techniques, the same computer can be used for many of the runs of interest. When this limit has been reached in a particular computer, the only solution is to have a system for dynamic program segmentation (i.e., where sections of logic are automatically rolled into and out of core during the course of the runs). Also of significant benefit to the user is a computer operating system which offers the capabilities just mentioned as well as the ability to selectively modify and recompile any routine previously stored away, and to use the newly compiled version in the same run.

6. In order to inhibit vast amounts of unnecessary printout, most SEADUCER subroutines have a print option in a common block which can be set. Since SEADUCER is so large and since plotting hardware and software are so nonstandard among computer installations, the information which needs to be plotted from SEADUCER is output on cards or magnetic tape in a form convenient for loading into a separate plotting program.

NETWORK TYPES (GENERAL DESCRIPTION)

All networks input by the user must have a special type number associated with them. The routine associated with this particular type number is preprogrammed to compute the elements of a specific form of the matrix (generally Z-form) as a function of specified independent variables (frequency in all applications of transducer analysis and

design). The computations are in general a function of (1) the independent variable, (2) the sign convention assumed for the network, (3) the number of ports, and (4) the port numbering originally specified.

A library of the network types encountered in transducer analysis presently exists. It should be noted that this library is continually expanding as different networks are used, and may be expanded to include other matrix forms or other physical problems. Specific types already implemented are described in Appendix B.

The user can specify types of networks other than those available in the existing library with the following specifications:

(1) network equations (matrix form; element equations),

(2) port sign conventions and numbering, and

(3) definitions of the input constants needed to compute the network matrix elements.

If the network under consideration is actually composed of a number of two-port networks cascaded together, the user may take advantage of a short-cut technique used widely for transducer problems. Each piece is simply considered as a network having the same name as the composite except for an additional number of the right side of the name which designates piece number. The program automatically cascades the A-form matrices representing each piece of the same name together to acquire the matrix for the composite network, called a section.

INTERCONNECTION TABLE

All interconnections of linear networks may be considered to be single networks themselves having similar properties, i.e., sign conventions, port numbering, boundary conditions, and names. The *accessible ports* are the ports of the interconnection, and *network ports* are the ports of the component networks. All connections involve *just* one accessible port and *at least* one network port. The interconnection table is a description of the interconnection for the computer program and contains sufficient information to allow complete non-ambiguous reconstruction of the interconnection.

Basically, for each connection, the following information is required to describe the interconnection:

(1) connection type (i.e., series or parallel),

(2) sign convention at the connection,

(3) accessible port name, and

(4) names of all involved network ports.

For example, consider the interconnection shown in figure 6.

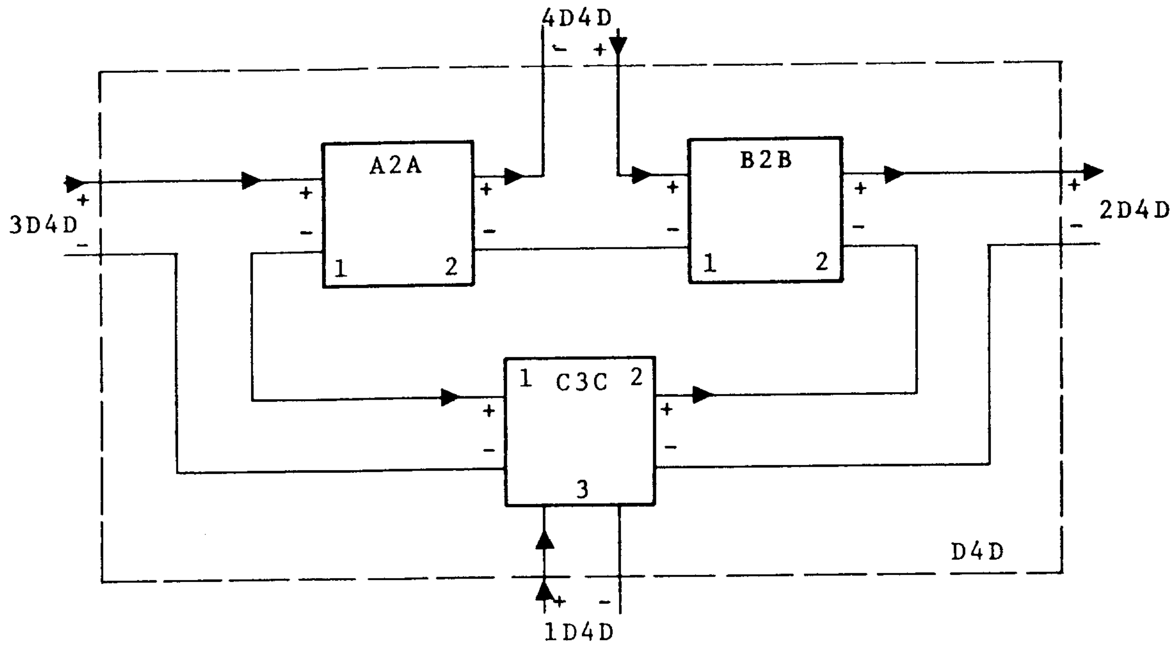


Figure 6. Example of Interconnected Array of Networks.

The following equations relate the voltage and currents at the accessible ports to the voltages and currents at the network ports:

(1) $E_1^D = E_3^C, \qquad I_1^D = I_3^C$

(2) $E_2^D = E_2^B + E_2^C, I_2^D = I_2^B = I_2^C$

(3) $E_3^D = E_1^A + E_1^C, I_3^D = I_1^A = I_1^C$

(4) $E_4^D = E_1^B - E_2^A, I_4^D = I_1^B = I_1^A$

The information contained in these equations can then be transferred into an interconnection table as follows:

S ++1D4D,++3C3C

S ++2D4D, ++2B2B, ++2C3C

S ++3D4D, ++1A2A, ++1C3C

S ++4D4D, -+2A2A, ++1B2B

where S denotes series connection, and signs are for voltage and current (or force and velocity, etc.), respectively.

The interconnection table (or *port table*) is a basic input into the computer program. Each interconnection must be described via its own interconnection table. This information is stored and defines the system of linear equations that is to be solved for the program.

A powerful feature of Seaducer is its provision for nesting of interconnection tables. Therefore, by judiciously choosing interconnection tables, the user can substructure his problem so that portions of the entire network which involve changes in the physical characteristics of components can be studied in depth without recomputing the entire network. (See Appendices C and D.)

CATALOG

The program utilizes a master storage area to retain all input data as well as computed variables and matrices for the individual and combined networks. As each new network is encountered, this area is dynamically allocated in the sense that pointers (subscripts) are set and stored away in the catalog. The catalog stores the following:

(1) network name,

(2) matrix size,

(3) piece number (for cascaded pieces),

(4) total number of pieces (for a section composed of cascaded pieces),

(5) network type,

(6) total amount of storage reserved for basic input values and permanently stored computed quantities, and

(7) location in master storage area for network with above properties.

For example, the catalog for the network shown in figure 6 might be

	Name	Matrix size	Piece no.	Total number of pieces	Network type	Data storage	Location in master storage
1	DD	4	0	0	0	0	1
2	AA	2	0	1	0	0	65
3	AA	2	1	1	1	7	81
4	BB	2	0	1	0	0	104
5	BB	2	1	1	1	7	120
6	CC	3	1	0	11	34	143

It should be pointed out that for each network port, twice the amount of storage needed is allocated to allow the user storage for different forms (Z-form, A-form, etc.) of the matrix other than that provided by the calculation of the "*network type*" subprogram. In summary, the catalog is used to handle the tedious bookkeeping task involved in the storage of the data and matrices of each network involved in the interconnection.

BOUNDARY CONDITION SPECIFICATION

Boundary conditions must be specified when the process of compaction, or decompaction, is to be carried out. Recall that compaction, as described under Theoretical Description of Multiport Interconnection Technique, is the process of removing undesired ports from the interconnection through application of *trivial* boundary conditions (open circuit or short circuit). The compaction, as done automatically by the program, always assumes zero left-hand side in the equations relating variables at the undesired ports. This effectively shorts a series port and opens a parallel port. Compaction is called automatically for interconnections of the same name which have fewer ports in a suceeding interconnection table. For example, if an interconnection table exists for A6B, and the name A4B appeared in a later interconnection table, then A6B would automatically be reduced to A4B *assuming ports 5 and 6 to be the undesired ports.*

The *decompaction* process is the means of determining voltages and currents at each port of every multiport network in the interconnection subject to sufficient boundary conditions specified by the user. The generalized decompaction process is currently not available, although the force and velocity at the edge of each piece of a 3-3 mode ceramic stack can be found, and decompaction can be done for all cascaded two-port networks.

CONTROL PROGRAM

The program is run by a user-supplied control routine that contains the problem specification. This control routine defines the interconnection tables, defines the network type for each network name appearing in an interconnection table, and specifies the calculations and output to be performed. The control program is a FORTRAN routine supplied by the user which allows added generality for the solution of the user's specific problems. Essentially, a library of subroutines is provided to perform various operations pertinent to the solution of any problem which can be represented by an interconnection of multiport networks. Examples of the control routines used in the solution of several different types of problems are presented in the appendices. Also included in Appendix A are write-ups of all subroutines available with the present program.

The first step to be taken in every control routine is to define the interconnection topology, or port table. This is done by calling a subroutine, LDPORT, once for each accessible port, by specifying the names of the network ports involved in the connection, and by specifying the connection's sign conventions and whether it is series or parallel.

Next, each network port is specified by calling the appropriate (corresponding to network type) routine that stores in the master storage area information that will allow the computation of the impedance (or similar form) matrix for the network. The calculation of the impedance matrix actually takes place in a separate routine if the matrix is a function of an independent variable (e.g., frequency). In other words, every network type has a routine associated with it that stores in the master storage area pertinent data about the network, and calculates the impedance matrix if the matrix is not a function of another independent variable. However, if the impedance matrix is a function of an independent variable, the calculation of the matrix takes place within another routine that is called during the cycling of the independent variable.

The impedance matrix for the entire network is found by effectively pre- and post-multiplying by the [C] and [D] matrices as described under Theoretical Description of Multiport Interconnection Technique. This operation is performed in subroutine BLDKKL. *Actual storage and matrix-multiplication is not required due to the nature of the [C] and [D] matrices.*

The steps described above are the basic steps that are performed in almost all control routines. As mentioned previously, the user can perform any calculations that are necessary and supply all print options.

PROGRAM CONVERSION FROM DOUBLE PRECISION TO SINGLE PRECISION

A consistent programming convention has been used throughout the computer program in order to facilitate the straightforward conversion from double precision to single precision. The following two types of changes are required:

1. Cards to be deleted for the single precision version contain the name of the routine starting in Column 73.
2. Cards to be changed contain the name of the routine starting in Column 73, immediately followed by an *.

Example

Double Precision

```
SUBROUTINE DCACSH (DINR, DINI, DOUTR, DOUTI)
DOUBLE PRECISION DINR, DINI, DOUTR, DOUTI, DTOUTR, DTOUTI  DCACSH
DOUBLE PRECISION DCANG1, DSQRT, DLOG                       DCACSH
.
.
.
DOUTR = DLOG (DSQRT(DTOUTR*DTOUTR+DTOUTI*DTOUTI))          DCACSH*
.
.
.
```

Single Precision

```
SUBROUTINE DCACSH (DINR, DINI, DOUTR, DOUTI)
delete
delete
.
.
.
DOUTR = ALOG(SQRT(DTOUTR*DTOUTR+DTOUTI*DTOUTI))
.
.
.
```

SUMMARY

This section has attempted to provide a description of the computer program in terms that are useful for non-programmers as well as programmers. Due to the general nature of the program package, a clear-cut description of its use is not possible without first defining a problem. For this reason, several examples are included in the appendices to show the user how to construct a control routine for the solution of a particular problem. *The use of a FORTRAN control routine for each different data set allows the user the full generality of the programming system for physical simulation of his specific problem.*

BIBLIOGRAPHY

1. *Notes for Seminar on Transducer Array Analysis and Evaluation*, Transducer Division, Naval Undersea Warfare Center, Intra-Division Memo No. D604-160, June, 1965.

2. H. J. Carlin and A. B. Giordano, *Network Theory: An Introduction to Reciprocal and Nonreciprocal Circuits*, Prentice-Hall, Englewood Cliffs, N.J., 1964, Chapter 3.

APPENDIX A

Program Description

Introduction

Presented in this appendix are write-ups describing the primary common storage blocks and all subroutines in the computer program. The primary common blocks are given in order to provide easy reference, and to avoid having to describe a common block several times. The subroutine write-ups describe the basic functions of the routines, and define the variables in the parameter lists.

Packed and Unpacked Network Names

Network names appear throughout the program in two forms, referred to as packed and unpacked. A network name in the packed form is one that has not been decoded by subroutine UNPACK. The name still contains port number, total number of ports for the network, and the piece number if applicable, as well as a terminating $. An unpacked name is simply the two letter network designation assigned by the user.

Description of the Primary Common Blocks

COMMON / / DATA(size=MXDATA)

Blank common is used exclusively as the master storage area discussed in Section 4.4.

COMMON / DTA TOT / MX DATA

MX DATA - total storage dimensioned for master storage area

COMMON / DTA SUB / I DTA SB

I DTA SB - counter for the number of data cells which have been allocated in the master storage area

COMMON / CPT WRD / N BYT P W, N B P BYT

N BYT P W - number of bytes (1 byte=1 Hollerith character) per word for the particular machine being used

N B P BYT - number of bits per byte

COMMON / PRT OFF / NO PRT

NO PRT - print flag
= 0 indicates print
≠ 1 suppresses print

COMMON / BASIC 8 / D F, D OMEGA, D PI

D F - frequency

D OMEGA - 2*pi*frequency

D PI - 3.141592653589

```
COMMON / CATALG / NAME(100), MTR SIZ(100), I PC(100),
    N PC TOT(100), I TYPE(100), N DT STR(100), LOC(100), I CLG SB
```

This area is used for the master storage area catalog.

NAME	- network name(unpacked)
MTR SIZ	- matrix size
I PC	- piece number (0 if not applicable)
N PC TOT	- total number of pieces with this network name(0 if not applicable)
I TYPE	- network type(0 if not applicable)
N DT STR	- amount of data storage required for this network in addition to the matrix storage
LOC	- index into master storage where information pertinent to this particular network is located
I CLG SB	- total number of entries that have been made into the catalog.

```
COMMON / PRT TBL / NET SP(100), I SIGN C(100), I SIGN D(100),
                   J PORT(100), N PORTS(100), NET NAM(100),
                   NUM APO(100), NUM NPO(100), N AHEAD(100),
                   N BACK(100), LC J ROW(100), N PRT SB
```

This area is used for the interconnection (or port) table.

NET SP - flag denoting either series or parallel connection

I SIGN C - sign associated with voltage(or force)

I SIGN D - sign associated with current (or velocity)

J PORT - the network port number

N PORTS - total number of ports associated with this particular network

NET NAM - network name(unpacked)

NUM APO - accessible port order number. Accessible ports are ordered (NUM APO = J PORT), however, for network ports this is the accessible port number to which the network port is connected

NUM NPO - network port order number(negative for accessible ports)

N AHEAD - a subscript that is a pointer to the entry in the table which has the next higher network port order for network ports, and next higher accessible port order for accessible ports

N BACK - subscript that is a pointer to the entry that has next lower network port order for network ports, and next lower accessible port order for accessible ports

LC J ROW - starting location in master storage for port information

N PRT SB - number of entries currently in the port table.

```
COMMON/ CA 2BY2 /IA11R,IA21R,IA12R,IA22R, IA11I,IA21I,IA12I,IA22I
```

Indices for referencing complex quantities of a 2 by 2 A-form matrix

```
COMMON/ CZ 2BY2 /IZ11R,IZ21R,IZ12R,IZ22R, IZ11I,IZ21I,IZ12I,IZ22I
```

Indices for referencing complex quantities of a 2 by 2 Z-form matrix

```
COMMON/ CY 2BY2 /IY11R,IY21R,IY12R,IY22R, IY11I,IY21I,IY12I,IY22I
```

Indices for referencing complex quantities of a 2 by 2 Y-form matrix

```
COMMON / CZ 3BY3 /
    IZ11R, IZ21R, IZ31R, IZ12R, IZ22R, IZ32R, IZ13R, IZ23R, IZ33R,
    IZ11I, IZ21I, IZ31I, IZ12I, IZ22I, IZ32I, IZ13I, IZ23I, IZ33I
```

Indices for referencing complex quantities of a 3 by 3 Z-form matrix

```
COMMON / CY 3BY3 /
    IY11R, IY21R, IY31R, IY12R, IY22R, IY32R, IY13R, IY23R, IY33R,
    IY11I, IY21I, IY31I, IY12I, IY22I, IY32I, IY13I, IY23I, IY33I
```

Indices for referencing complex quantities of a 3 by 3 Y-form matrix

Subroutine Descriptions

Subroutine descriptions have been grouped according to the functions performed, and are preceeded by an alphabetical index to allow easy access if the routine name is known. The subroutines have also been classified to aid the user in determining priorities in studying the write-ups. The classifications are as follows:

*	- routines for which the purpose should be understood by the user for operation of the program,
**	- routines which do not require detailed understanding by the user,
***	- routines that are used internally in the program, and will probably not be directly needed by the user.

LDPORT *

LDPORT loads into the interconnection table the description of the network ports comprising a particular accessible port. For calls to this routine, the accessible ports should be defined in consecutive and ascending order.

calling sequence:

```
CALL LDPORT(IH SP, IPORT)
```

input:

IH SP - flag denoting series (S) or parallel (P) interconnection (left justified Hollerith word).

IPORT - a string of characters (terminated by $) which describes the accessible port by name, and each network port involved in the connection.

example:

```
CALL LDPORT('S', '8K8D,→2D3A,1B2E,$')
```

The eighth accessible port of K8D is series connected to the second port of D3A and the first port of B2E.

printout:

Each call to LDPORT prints the information being loaded.

BLDMTR *

BLDMTR constructs the matrix relating variables at the accessible ports of a network for which an interconnection table has already been loaded. This is performed by automatically chaining successive calls to BLDKKL and RDCPRT. This matrix may be of size less than or equal to that size as loaded in the port table.

calling sequence:

CALL BLDMTR(LH ANA)

input:

LH ANA - packed name terminated by $ (two computer words), of the interconnected network.

BLDKKL **

BLDKKL initiates the computation of the individual network matrices (through CASCDE), and using these matrices computes the matrix relating variables at the accessible ports by pre- and post-multiplying by the C and D matrices which are determined by Kirchoff's laws (without actual storage of C and D).

calling sequence:

```
CALL BLDKKL(LH ANA)
```

input:

LH ANA - packed name terminated by $ (two computer words), of the interconnection network.

RDCPRT **

RDCPRT reduces a network by the compaction process described in Section 3.

Note: after reducing AnA to AmA do not reduce AkA to AmA for k greater than m.

calling sequence:

```
CALL RDCPRT(LH ANA, LH AMA)
```

input:

LH ANA - packed name terminated by $ (two computer words), of the original network.

LH AMA - packed name terminated by $ (two computer words), of the new smaller network.

LDFREQ *

LDFREQ loads the frequency into a common area named BASIC8, as well as the corresponding value of omega (2. x pi x frequency).

calling sequence:

```
CALL LDFREQ(DDF)
```

input:

DDF - frequency

printout:

Value of frequency (controlled by COMMON / PRT OFF / NO PRT)

UPPTBL ***

UPPTBL updates the interconnection table with network port order numbers, and forward and backward pointers to network ports.

calling sequence:

CALL UPPTBL

FNDLCJ ***

FNDLCJ obtains the location in master storage for all matrices needed for a particular network, and allocates storage for all networks for which storage has not been set aside. Additional storage is also set aside for networks that will automatically be reduced in size.

calling sequence:

CALL FNDLCJ(N FIRST, N LAST)

input:

N FIRST - entry in interconnection table to begin processing.

N LAST - entry in interconnection table to end processing.

ALOCAT **

ALOCAT allocates storage in the master storage area by inserting a new entry into the catalog.

calling sequence:

```
CALL ALOCAT(NAM MTR, M NEW, NMT TOT)
```

input:

NAM MTR - unpacked name of network to be added to catalog.

M NEW - size of matrix.

NMT TOT - total number of storage locations required.

CHKSTR **

CHKSTR checks to insure that the current total master storage area has not exceeded the allowable storage limit, MXDATA.

calling sequence:

```
CALL CHK STR(I DTA CH)
```

input:

I DTA CH - counter which is compared to total allowable storage limit, MX DATA.

FNDNET **

FNDNET searches the interconnection table for a particular interconnection denoted by input name, and returns the first and last entries in the port table for that name.

calling sequence:

```
CALL FND NET(LH ANA, N FIRST, N LAST)
```

input:

LH ANA - packed name terminated by $ (two computer words), of the interconnection network.

output:

N FIRST - first entry for this interconnection.

N LAST - last entry for this interconnection.

LOCMTR **

LOCMTR returns the location in master storage of the network specified through input name and matrix size.

calling sequence:

```
I = LOCMTR(I NAME, I MTR SZ)
```

input:

I NAME - network name (unpacked).

I MTR SZ - matrix size.

output:

I - master storage location (0 if not found).

LOCNAM **

LOCNAM returns the location in master storage of the first network specified by input name. No check is made on matrix size.

calling sequence:

I = LOCNAM(INAME)

input:

I NAME - network name (unpacked).

output:

I - master storage location (0 if not found).

FNDMTR **

FNDMTR returns to the calling program the entry number in the master storage area catalog that agrees with the input name and matrix size.

calling sequence:

```
CALL FNDMTR(I NAME, I MTR SZ, I SUB)
```

input:

I NAME - network name (unpacked).

I MTR SZ - matrix size.

output:

I SUB - subscript in master storage area catalog (0 if not found).

FNDNAM **

FNDNAM searches the catalog for the first occurence of an input name and returns the entry number in the catalog. Note that no check is made on matrix size.

calling sequence:

```
CALL FNDNAM(I NAME, I SUB)
```

input:

I NAME - network name (unpacked).

output:

I SUB - subscript in master storage area catalog (0 if not found).

CASCDE **

CASCDE computes the individual (typed) network matrices through a routine called TYPCAL, and cascdes (or multiplies) all 2 by 2 matrices that are flagged appropriately and stores the product matrix into the primary storage area for that section.

calling sequence:

CALL CASCDE(ISUB)

input:

I SUB - entry in master storage catalog for the product matrix.

note: An additional input parameter is supplied via COMMON/C FLG AZ/N ZAY

N ZAY - flag indicating form of cascaded matrix desired.
0 indicates convert A to Z form for primary area
1 indicates leave in A form
2 indicates convert A to Y form for primary area

TYPCAL ***

TYPCAL checks the network type of the entry in the catalog specified by input, and branches to the proper routine to calculate the matrix describing the network.

calling sequence:

```
CALL TYPCAL(IC SUB)
```

input:

IC SUB - catalog entry number of the network for which matrix computations are to be performed.

LDDT1 *

LDDT1 loads data for a type 1 network which represents a straight piece.

calling sequence:

```
CALL LDDT1(LH ANAI, RHO, AREA, AID, AOD, PIECL, CR, CI, CM)
```

input:

LH ANAI	- piece name (packed) terminated by $ (two words).
RHO	- density.
AREA	- cross-sectional area.
AID	- inner diameter.
AOD	- outer diameter.
PIECL	- length of single piece.
CR	- real part of velocity of sound in medium.
CI	- imaginary part of velocity of sound.
CM	- multiplier for complex velocity of sound.

note: If CI or CM is non zero, then the missing parameter will be computed from CM = CI/CR.

printout:

Values of input data (controlled by COMMON / PRT OFF / NO PRT).

TYPE1 ***

TYPE1 computes the matrix for a type 1 network as a function of frequency.

calling sequence:

```
CALL TYPE1(NAMTR, NNDTA)
```

input:

NAMTR - master storage location for matrix.

NNDTA - master storage location for data.

LDDT2 *

LDDT2 loads data for a type 2 network which represents a conical piece.

calling sequence:

```
CALL LDDT2(LH ANAI,RHO, A1,AID1,AOD1, A2,AID2,AOD2, PIECL, CR,CI,CM)
```

input:

LH ANAI	- piece name (packed) terminated by $ (two words).
RHO	- density.
A1	- cross-sectional area of end 1.
AID1	- inner diameter of end 1.
AOD1	- outer diameter of end 1.
A2	- cross-sectional area of end 2.
AID2	- inner diameter of end 2.
AOD2	- outer diameter of end 2.
PIECL	- length of single piece.
CR	- real part of velocity of sound in medium.
CI	- imaginary part of velocity of sound.
CM	- multiplier for complex velocity of sound.

note: If CI or CM is non zero, then the missing parameter will be computed from CM = CI/CR.

printout:

Values of input data (controlled by COMMON / PRT OFF / NO PRT).

TYPE2 ***

TYPE2 computes the matrix for a type 2 network as a function of frequency.

calling sequence:

```
CALL TYPE2(NAMTR, NNDTA)
```

input:

NAMTR - master storage location for matrix.

NNDTA - master storage location for data.

LDDT4 *

LDDT4 loads data for a type 4 network which represents an ideal transformer.

calling sequence:

```
CALL LDDT4(LH ANAI, SEC TRN)
```

input:

LH ANAI - piece name (packed) terminated by $ (two words).

SEC TRN - secondary to primary turns ratio.

printout:

Values of input data (controlled by COMMON / PRT OFF / NO PRT).

LDDT5 *

LDDT5 loads data for a type 5 network which is an arbitrary matrix.

calling sequence:

CALL LDDT5(LH ANAI, ZR, ZI)

input:

LH ANAI - section name(packed) terminated by $ (two words).

ZR - real part of Zij array.

ZI - imag part of Zij array.

printout:

Values of input data (controlled by COMMON / PRT OFF / NO PRT).

LDDT7 *

LDDT7 loads data for a type 7 network which is a rational polynomial fit to an impedance or mobility matrix.

calling sequence:

CALL LDDT7(LH ANAI, FACTOR, IFORM)

input:

LH ANAI - piece name (packed) terminated by $ (two words).

FACTOR - scale factor for all coefficients.

IFORM - flag to determine matrix form,
= 0 Z form (impedance)
= 1 Y form (admittance) = inverse of Z form.

data card input for polynomial fit coefficients:

Card 1 (FORMAT(3I5, 16A4))

N ORD N - order of numerator polynomial.

N ORD D - order of denominator polynomial.

N SYM FG - symmetry flag for loading matrix coefficients.
= -1 indicates negative symmetry across diaginal.
= 0 indicates no symmetry.
= +1 indicates symmetry across diagonal.

note: if symmetry exists then only coefficients for elements in upper triangle are needed and should be ordered by columns as (1,1), (1,2), (2,2), (1,3),..., (N,N). However, if no symmetry exists then the order should be (1,1), (2,1), ..., (N,1), (1,2), (2,2), ...

IHEAD - 16 word alphanumeric heading to identify coefficients.

Cards 2 - NORDN+1 (FORMAT(E17.10, 1X, E17.10))

DCR - real part of numerator coefficient in ascending powers of the independent variable.

DCI - imaginary part of numerator coefficient in ascending powers of the independent variable.

Cards NORDN+2 - NORDN+NORDD+1 (FORMAT(E17.10, 1X, E17.10))

DCR - real part of denominator coefficient in ascending powers of the independent variable.

DCI - imaginary part of denominator coefficient in ascending powers of the independent variable.

printout:

Values of input data (controlled by COMMON / PRT OFF / NO PRT).

TYPE7 ***

TYPE7 computes the matrix for a type 7 network as a function of frequency.

calling sequence:

```
CALL TYPE7(NAMTR, NNDTA)
```

input:

NAMTR - master storage location for matrix.

NNDTA - master storage location for data.

LDDT8 *

LDDT8 loads data for a type 8 network which is a voltage to voltage converter.

calling sequence:

```
CALL LDDT8(LH ANAI, ZIR, ZII, ZGR, ZGI, ALPR, ALPI)
```

input:

LH ANAI	- piece name (packed) terminated by $ (two words).
ZIR	- real part of amplifier input impedance (ohms).
ZII	- imag part of amplifier input impedance (ohms).
ZGR	- real part of amplifier output impedance (ohms).
ZGI	- imag part of amplifier output impedance (ohms).
ALPR	- real part of amplification factor.
ALPI	- imag part of amplification factor.

printout:

Values of input data (controlled by COMMON / PRT OFF / NO PRT).

LDDT9 *

LDDT9 loads data for a type 9 network which is a voltage to current converter.

calling sequence:

```
CALL LDDT9(LH ANAI, ZIR, ZII, ZOR, ZOI, BETAR, BETAI)
```

input:

LH ANAI	- piece name (packed) terminated by $ (two words).
ZIR	- real part of amplifier input impedance (ohms).
ZII	- imag part of amplifier input impedance (ohms).
ZOR	- real part of amplifier output impedance (ohms).
ZOI	- imag part of amplifier output impedance (ohms).
BETAR	- real part of voltage to current gain (mhos).
BETAI	- imag part of voltage to current gain (mhos).

printout:

Values of input data (controlled by COMMON / PRT OFF / NO PRT).

LDDT11 *

LDDT11 loads data for a type 11 network which is a 3-3 mode ceramic stack.

calling sequence:

```
CALL LDDT11(LH ANAI, NPCS, RHO, AREA, AID, AOD, PIECL,
DE33TR,DE33TI,DE33TM, DG33R,DG33I,DG33M, DS33DR,DS33DI,DS33DM)
```

input:

LH ANAI	- section name(packed) terminated by $ (two words).
NPCS	- total number of pieces for this ceramic section.
RHO	- density.
AREA	- cross-sectional area.
AID	- inner diameter.
AOD	- outer diameter.
PIECL	- length of single piece.
DE33TR	- real part of E33T (always double precision).
DE33TI	- imag part of E33T (always double precision).
DE33TM	- E33T multiplier (always double precision).
DG33R	- real part of G33R (always double precision).
DG33I	- imag part of G33I (always double precision).
DG33M	- G33 multiplier (always double precision).
DS33DR	- real part of S33D (always double precision).
DS33DI	- imag part of S33D (always double precision).
DS33DM	- S33D multiplier (always double precision).

note: For ceramic parameters if either I or M is zero, the missing parameter will be computed by M=-I/R.

printout:

Values of input data (controlled by COMMON/PRT OFF/NO PRT).

TYPE11 ***

TYPE11 computes the matrix for a type 11 network as a function of frequency.

calling sequence:

```
CALL TYPE11(NAMTR, NNDTA)
```

input:

NAMTR - master storage location for matrix.

NNDTA - master storage location for data.

T11SBR ***

T11SBR performs operations required by type 11, and stores into common areas used in type 11 calculations.

calling sequence:

CALL T11SBR

LDDT14 *

LDDT14 loads data for a type 14 network which is a 3-1 mode ceramic bar.

calling sequence:

```
CALL LDDT14(LH ANAI, RHO, THICK, FOIL W, PIEC L,
DE33TR,DE33TI,DE33TM, DG31R,DG31I,DG31M, DS11ER,DS11EI,DS11EM)
```

input:

LH ANAI	- section name(packed) terminated by $ (two words).
RHO	- density.
THICK	- thickness.
FOIL W	- foil width.
PIECL	- length of single piece.
DE33TR	- real part of E33T (always double precision).
DE33TI	- imag part of E33T (always double precision).
DE33TM	- E33T multiplier (always double precision).
DG31R	- real part of G31R (always double precision).
DG31I	- imag part of G31I (always double precision).
DG31M	- G31 multiplier (always double precision).
DS11ER	- real part of S11E (always double precision).
DS11EI	- imag part of S11E (always double precision).
DS11EM	- S11E multiplier (always double precision).

note: For ceramic parameters if either I or M is zero, the missing parameter will be computed by M=-I/R.

printout:

Values of input data (controlled by COMMON / PRT OFF / NO PRT).

TYPE14 ***

TYPE14 computes the matrix for a type 14 network as a function of frequency.

calling sequence:

```
CALL TYPE14(NZMTR, NNDTA)
```

input:

NZMTR - master storage location for matrix.

NNDTA - master storage location for data.

LDDT15 *

LDDT15 loads data for a type 15 network which is a 3-1 mode ceramic tube.

calling sequence:

```
CALL LDDT15(LH ANAI, RHO, R IN D, R OUT D, PIEC L,
DE33TR,DE33TI,DE33TM, DG31R,DG31I,DG31M, DS11ER,DS11EI,DS11EM)
```

input:

LH ANAI	- section name(packed) terminated by $ (two words).
RHO	- density.
R IN D	- inner diameter.
R OUT D	- outer diameter.
PIECL	- length of single piece.
DE33TR	- real part of E33T (always double precision).
DE33TI	- imag part of E33T (always double precision).
DE33TM	- E33T multiplier (always double precision).
DG31R	- real part of G31R (always double precision).
DG31I	- imag part of G31I (always double precision).
DG31M	- G31 multiplier (always double precision).
DS11ER	- real part of S11E (always double precision).
DS11EI	- imag part of S11E (always double precision).
DS11EM	- S11E multiplier (always double precision).

note: For ceramic parameters if either I or M is zero, the missing parameter will be computed by M=-I/R.

printout:

Values of input data (controlled by COMMON / PRT OFF / NO PRT).

TYPE15 ***

TYPE15 computes the matrix for a type 15 network as a function of frequency.

calling sequence:

```
CALL TYPE15(NZMTR, NNDTA)
```

input:

NZMTR - master storage location for matrix.

NNDTA - master storage location for data.

T1415S ***

T1415S performs operations required by type 14 and type 15, and stores into common areas used in type 14 and type 15 calculations.

calling sequence:

CALL T1415S

TP1415 ***

TP1415 performs operations required by type 14 and type 15 networks.

calling sequence:

```
CALL TP1415
```

LDDT20 *

LDDT20 loads data for a type 20 network which is a linear transformer.

calling sequence:

```
CALL LDDT20(LH ANAI, RP, HLP, RO, HLO, RS, HLS, PHI)
```

input:

LH ANAI	- piece name (packed) terminated by $ (two words).
RP	- copper loss in primary.
HLP	- winding inductance in primary.
RO	- core loss.
HLO	- magnetizing inductance.
RS	- copper loss in secondary.
HLS	- winding inductance in secondary.
PHI	- secondary to primary turns ratio.

printout:

Values of input data (controlled by COMMON / PRT OFF / NO PRT).

TYPE20 ***

TYPE20 computes the matrix for a type 20 network as a function of frequency.

calling sequence:

```
CALL TYPE20(NAMTR, NNDTA)
```

input:

NAMTR - master storage location for matrix.

NNDTA - master storage location for data.

LDDT21 *

LDDT21 loads data for a type 21 network which is a series impedance.

calling sequence:

```
CALL LDDT21(LH ANAI, RS, HLS, CS)
```

input:

LH ANAI	-	piece name (packed) terminated by $ (two words).
RS	-	resistance (Ohms).
HLS	-	inductance (Hy).
CS	-	capacitance (Fy).

printout:

Values of input data (controlled by COMMON / PRT OFF / NO PRT).

TYPE21 ***

TYPE21 computes the matrix for a type 21 network as a function of frequency.

calling sequence:

```
CALL TYPE21(NAMTR, NNDTA)
```

input:

NAMTR - master storage location for matrix.

NNDTA - master storage location for data.

LDDT22 *

LDDT22 loads data for a type 22 network which is a parallel impedance.

calling sequence:

```
CALL LDDT22(LH ANAI, RS, HLS, CS)
```

input:

- LH ANAI - piece name (packed) terminated by $ (two words).
- RS - resistance (Ohms).
- HLS - inductance (Hy).
- CS - capacitance (Fy).

printout:

Values of input data (controlled by COMMON / PRT OFF / NO PRT).

TYPE22 ***

TYPE22 computes the matrix for a type 22 network as a function of frequency.

calling sequence:

```
CALL TYPE22(N MTR, N DTA)
```

input:

N MTR - master storage location for matrix.

N DTA - master storage location for data.

LDDT24 *

LDDT24 loads data for a type 24 network which is a series admittance.

calling sequence:

```
CALL LDDT24(LH ANAI, RP, HLP, CP)
```

input:

LH ANAI - piece name (packed) terminated by $ (two words).

RP - resistance (Ohms).

HLP - inductance (Hy).

CP - capacitance (Fd).

printout:

Values of input data (controlled by COMMON / PRT OFF / NO PRT).

TYPE24 ***

TYPE24 computes the matrix for a type 24 network as a function of frequency.

calling sequence:

CALL TYPE24(NAMTR, NNDTA)

input:

NAMTR - master storage location formatrix.

NNDTA - master storage location for data.

LDDT25 *

LDDT25 loads data for a type 25 network which is a parallel admittance.

calling sequence:

```
CALL LDDT25(LH ANAI, RP, HLP, CP)
```

input:

LH ANAI - piece name (packed) terminated by $ (two words).

RP - resistance (Ohms).

HLP - inductance (Hy).

CP - capacitance (Fd).

printout:

Values of input data (controlled by COMMON / PRT OFF / NO PRT).

TYPE25 ***

TYPE25 computes the matrix for a type 25 network as a function of frequency.

calling sequence:

```
CALL TYPE25(N MTR, N DTA)
```

input:

N MTR - master storage location for matrix.

N DTA - master storage location for data.

LDDT26 *

LDDT26 loads data for a type 26 network which is a differential input operational amplifier.

calling sequence:

```
CALL LDDT26(LH ANAI, R1,C1, R2,C2, RD,CD, R3,HL3,
OMEGA1, OMEGA2, OMEGA3)
```

input:

LH ANAI	- section name(packed) terminated by $ (two words).
R1	- input resistance (Ohms).
C1	- input capacitance (farads).
R2	- input resistance (Ohms).
C2	- input capacitance (farads).
RD	- differential input resistance (Ohms).
CD	- differential input capacitance (farads).
R3	- output resistance (Ohms).
C3	- output capacitance (farads).
HL3	- output inductance (henries).
AO	- dc open loop gain.
OMEGA1	- first pole frequency of open loop transfer function (1/sec).
OMEGA2	- second pole frequency of open loop transfer function (1/sec).
OMEGA3	- third pole frequency of open loop transfer function (1/sec).

printout:

Values of input data (controlled by COMMON / PRT OFF / NO PRT).

TYPE26 ***

TYPE26 computes the matrix for a type 26 network as a function of frequency.

calling sequence:

```
CALL TYPE26(N MTR, N DTA)
```

input:

N MTR - master storage location for matrix.

N DTA - master storage location for data.

AIDOD **

AIDOD calculates either inner diameter, outer diameter, or area given the proper combination of the other two.

calling sequence:

```
CALL AIDOD(A, AID, AOD)
```

input/output (see tables below):

A	- area
AID	- inner diameter
AOD	- outer diameter

The following table shows the input quantities and output quantities for every combination of input.

input			output		
Area	ID	OD	Area	ID	OD
X	0	0	X	0	0
0	X	0	(insufficient data)		
0	0	X	C	0	X
X	X	0	X	X	C
X	0	X	X	C	X
0	X	X	C	X	X
X	X	X	X	X	X
0	0	0	(insufficient data)		

where X - non-zero input
C - calculated

caution: a zero input should be passed through a variable name, and not as a literal in the subroutine call since the value may be changed in the subroutine.

The following relationships are used in the computation and are valid for types 1, 2, and 11.

```
A = (pi/4)(OD**2 - ID**2)
ID = SQRT(OD**2 - 4A/pi)
OD = SQRT(4A/pi - ID**2)
```

LA2BY2 **

LA2BY2 loads indices for master storage for the A-form of a 2 port network (2x2 matrix) into common area CA2BY2.

calling sequence:

CALL LA2BY2

input:

N MTR - master storage location for matrix

LZ2BY2 **

LZ2BY2 loads indices for master storage for the Z-form of a 2 port network (2x2 matrix) into common area CZ2BY2.

calling sequence:

CALL LZ2BY2

input:

N MTR - master storage location for matrix

LZ3BY3 **

LZ3BY3 loads indices for master storage for the Z-form of a 3 port network (3x3 matrix) into common area CZ3BY3.

calling sequence:

CALL LZ3BY3

input:

N MTR - master storage location for matrix

LY2BY2 **

LY2BY2 loads indices for master storage for the Y-form of a 2 port network (2x2 matrix) into common area CY2BY2.

calling sequence:

CALL LY2BY2

input:

N MTR - master storage location for matrix

LY3BY3 **

LY3BY3 loads indices for master storage for the Y-form of a 3 port network (3x3 matrix) into common area CY3BY3.

calling sequence:

CALL LY3BY3

input:

N MTR - master storage location for matrix

LDDRIM ***

LDDRIM loads into the master storage area the real, imaginary, and multiplier supplied on input. Note that only the real(R) and either the imaginary(I) or multiplier(M) or both need be supplied and the missing parameter(input as zero) will be computed by M=-I/R. The parameters are stored in sequence using the present value of IDTASB which is the total number of storage cells used in master storage.

calling sequence:

```
CALL LDDRIM(DR, DI, DM)
```

input:

DR - real part.

DI - imaginary part.

input/output:

DM - multiplier (DM = -DI/DR).

LDSB11 ***

LDSB11 sets up a group of indices that enables easy referencing of network type 11 (3-3 mode ceramic stack) data. These indices are stored in common block COMN11.

calling sequence:

    CALL LDSB11(NDTA)

input:

NDTA - master storage location where data starts.

LS1415 ***

LS1415 sets up a group of indices that enables easy referencing of network type 14(3-1 mode ceramic bar) and type 15(3-1 mode ceramic tube) data. These indices are stored into common block CM1415.

calling sequence:

CALL LS1415(NDTA)

input:

NDTA - master storage location where data starts.

<u>FNDTMS</u> **

FNDTMS determines the total mass of all type 1, type2, and type11 networks.

<u>calling sequence</u>:

CALL FNDTMS

<u>printout</u>:

mass in MKS and English units (controlled by COMMON / PRT OFF / NO PRT).

FNDTL **

FNDTL determines the total length of all networks specified by input name for types 1, 2, 11, 14, and 15.

calling sequence:

CALL FNDTL(L NAMES, N NAMES)

input:

L NAMES - an array containing the names(unpacked) of sections to be used in total length computation.

N NAMES - number of names in the array L NAMES.

printout:

value of length (controlled by COMMON / PRT OFF / NO PRT).

MTRMOV **

MTRMOV moves a matrix of given size from one area in master storage to another area in master storage.

calling sequence:

```
CALL MTRMOV(NNEW, NOLD, MTRSIZ)
```

input:

NNEW	- master storage location where matrix is to be moved.
NOLD	- master storage location where matrix is stored.
MTRSIZ	- matrix size.

MTRMUL **

MTRMUL multiplies two matrices stored in master storage.

calling sequence:

CALL MTRMUL(LCNEW, LCOLDA, LCOLDB, MA, NA, MB, NB)

where (matrix NEW) = (matrix A) x (matrix B)

input:

LCNEW	- master storage location where product is to be stored.
LCOLDA	- master storage location where matrix A is stored.
LCOLDB	- master storage location where matrix B is stored.
MA	- number of rows of matrix A.
NA	- number of columns of matrix A.
MB	- number of rows of matrix B.
NB	- number of columns of matrix B.

note: LCNEW cannot coincide with either LCOLDA or LCOLDB, and NA must equal MB.

DLETRC **

DLETRC deletes specified rows and/or columns from a matrix and performs a scalar multiplication on the matrix.

calling sequence:

```
CALL DLETRC(NN OLD R, NN OLD I, M OLD, N OLD, I OUT, J OUT,
        NI OUT, NJ OUT, N NEW R, N NEW I, SCALAR)
```

input:

NN OLD R	- master storage location of real part of input matrix.
NN OLD I	- master storage location of imaginary part of input matrix.
M OLD	- number of rows in input matrix.
N OLD	- number of columns in input matrix.
I OUT	- array containing indices of rows to be deleted.
J OUT	- array containing indices of columns to be deleted.
NI OUT	- number of rows to be deleted.
NJ OUT	- number of columns to be deleted.
N NEW R	- master storage location of real part of output matrix.
N NEW I	- master storage location of imaginary part of output matrix.
SCALAR	- scale factor for output matrix.

LDIMTR **

LDIMTR loads an identity matrix of specified size into the desired master storage area.

calling sequence:

```
CALL LDIMTR(ISUB, MSIZ)
```

input:

ISUB - master storage location for unit matrix.

MSIZ - matrix size.

DECOM8 **

DECOM8 solves the system of equations AX = B for the vector X (INVFG = 0) or computes the inverse of the matrix A (INVFG = 1).

calling sequence:

```
CALL DECOM8(DA,NA, DAI,NAI, DAINV,NAINV, DAINVI,NAINVI,
        NSIZE, MDFA, INVFG)
```

input:

DA - array containing the real part of matrix A.

NA - starting subscript in DA.

DAI - array containg imaginary part of matrix A.

NAI - starting subscript in DAI.

output:

DAINV - array for storing the real part of A inverse.

input:

NAINV - subscript in DAINV to begin storing.

output:

DAINVI - array for storing imaginary part of A inverse.

input:

NAINVI - subscript into DAINVI to begin storing.

NSIZE - size of matrix A.

MDFA - matrix decomposition flag,
= 0, decompose matrix.
= 1, matrix has already been decomposed.

INVFG - either solve for vector X (INVFG = 0), or compute inverse of A (INVFG = 1).

ATOZ **

ATOZ converts a 2x2 matrix in the A-form to the Z-form.

calling sequence:

CALL ATOZ(N AMTR, N ZMTR)

input:

N AMTR - master storage location for A-form.

N ZMTR - master storage location for Z-form.

transformation:

Z11 = A11 / A21

Z12 = A12 - A11 A22 / A21

Z21 = 1 / A21

Z22 = -A22 / A21

ZTOA **

ZTOA converts a 2x2 matrix in the Z-form to the A-form.

calling sequence:

CALL ZTOA(N ZMTR, N AMTR)

input:

N ZMTR - master storage location for Z-form.

N AMTR - master storage location for A-form.

transformation:

A11 = Z11 / Z21

A12 = Z12 - Z11 Z22 / Z21

A21 = 1 / Z21

A22 = -Z22 / Z21

ATOY **

ATOY converts a 2x2 matrix in the A-form to the Y-form.

calling sequence:

```
CALL ATOY(N AMTR, N YMTR)
```

input:

N AMTR - master storage location for A-form.

N YMTR - master storage location for Y-form.

transformation:

$$Y11 = A22 / A12$$

$$Y12 = (A12\ A21 - A11\ A22) / A12$$

$$Y21 = 1 / A12$$

$$Y22 = -A11 / A12$$

YTOA **

YTOA converts a 2x2 matrix in the Y-form to the A-form.

calling sequence:

```
CALL YTOA(N YMTR, N AMTR)
```

input:

N YMTR - master storage location for Y-form.

N AMTR - master storage location for A-form.

transformation:

A11 = -Y22 / Y21

A12 = 1 / Y21

A21 = (Y12 Y21 - Y11 Y12) / Y21

A22 = Y11 / Y21

DACMUL **

DACMUL performs a complex accumulative multiplication.

calling sequence:

```
CALL DACMUL(DA, DB, DC, DD, DE, DF)
```

input:

DA - real part of first input number.

DB - imag part of first input number.

DC - real part of second input number.

DD - imag part of second input number.

input/output:

DE - real part of resultant.

DF - imag part of resultant.

the following steps are performed:

DE = DE + DA * DC - DB * DD

DF = DF + DA * DD + DB * DC

note: resultant variables may occupy the same locations as either input.

DCMMUL **

DCMMUL performs a complex multiplication.

calling sequence:

```
CALL DCMMUL(DA, DB, DC, DD, DE, DF)
```

input:

DA	- real part of multiplicand.
DB	- imag part of multiplicand.
DC	- real part of multiplier.
DD	- imag part of multiplier.

output:

DE	- real part of product.
DF	- imag part of product.

note: the result may occupy the same locations as either input.

DCMDIV **

DCMDIV performs a complex division.

calling sequence:

```
CALL DCMDIV(DA, DB, DC, DD, DE, DF)
```

input:

DA	- real part of dividend.
DB	- imag part of dividend.
DC	- real part of divisor.
DD	- imag part of divisor.

output:

DE	- real part of quotient.
DF	- imag part of quotient.

note: the result may occupy the same locations as either input.

DCRCIP **

DCRCIP computes the reciprocal of a complex number.

calling sequence:

```
CALL DCRCIP(DINR, DINI, DOUTR, DOUTI)
```

input:

DINR	-	real part of input.
DINI	-	imag part of input.

output:

DOUTR	-	real part of output.
DOUTI	-	imag part of output.

note: the result may occupy the same locations as either input.

DCSQRT **

DCSQRT computes the square root of a complex argument.

calling sequence:

```
CALL DCSQRT(DINR, DINI, DCSQTR, DCSQTI)
```

input:

DINR	- real part of argument.
DINI	- imag part of argument.

output:

DCSQTR	- real part of square root.
DCSQTI	- imag part of square root.

note: the result may occupy the same locations as the input.

DCANG1 **

DCANG1 returns the phase (in radians) of a complex number adjusted so that the result appears between -pi and pi.

calling sequence:

```
ANG = DCANG1(DX, DY)
```

where: ANG = ARC TAN(DY/DX).

DCACSH **

DCACSH calculates the complex inverse hyperbolic cosine, Y = ARC COSH(Z).

where: real Y = ln(|Z + SQRT(Z**2-1)|)

imag Y = ang(Z + SQRT(Z**2-1))

CALLING SEQUENCE:

```
CALL DCACSH(DINR, DINI, DOUTR, DOUTI)
```

input:

- DINR - real part of input, Z.
- DINI - imag part of input, Z.

output:

- DOUTR - real part of output, Y.
- DOUTI - imag part of output, Y.

note: the result may occupy the same locations as the input.

DSHCH **

DSHCH computes the hyperbolic sine and hyperbolic cosine of an argument.

calling sequence:

```
CALL DSHCH(DARG, DSINH, DCOSH)
```

input:

DARG - input argument.

output:

DSINH - hyperbolic sine of DARG.

DCOSH - hyperbolic cosine of DARG.

DCSNCS **

DCSNCS computes the sine and cosine of a complex argument.

calling sequence:

```
CALL DCSNCS(DARGR,DARGI, DSINR,DSINI, DCOSR,DCOSI)
```

input:

DARGR - real part of input argument.

DARGI - imag part of input argument.

output:

DSINR - real part of sine.

DSINI - imag part of sine.

DCOSR - real part of cosine.

DCOSI - imag part of cosine.

note: either result may occupy the same locations as the input.

DCSHCH **

DCSHCH computes the hyperbolic sine and cosine of a complex argument.

calling sequence:

```
CALL DCSHCH(DARGR,DARGI, DSINHR,DSINHI, DCOSHR,DCOSHI)
```

input:

DARGR - real part of input argument.

DARGI - imag part of input argument.

output:

DSINHR - real part of hyperbolic sine.

DSINHI - imag part of hyperbolic sine.

DCOSHR - real part of hyperbolic cosine.

DCOSHI - imag part of hyperbolic cosine.

note: either result may occupy the same locations as the input.

PRTMTR **

PRTMTR prints a square matrix that is in master storage.

calling sequence:

```
CALL PRTMTR(N MTR, MTR SIZ)
```

input:

N MTR - master storage location of matrix.

MTR SIZ - matrix size.

printout:

see above.

PRTMBN **

PRTMBN prints an M by N matrix that is in master storage.

calling sequence:

```
CALL PRTMBN(N MTR, MTR M, MTR N)
```

input:

N MTR - master storage location of matrix.

MTR M - number of rows in matrix.

MTR N - number of columns in matrix.

printout:

see above.

PRMARI **

PRMARI prints the magnitude, angle (either in degrees or radians), real, and imaginary parts of a complex number.

calling sequence:

```
CALL PRMARI(IHEAD, IANGLE, DREAL, DIMAG)
```

input:

IHEAD	-	flag that determines whether a heading should be printed (=0, no heading).
IANGLE	-	flag that specifies either degrees (=3hdeg) or radians.
DREAL	-	real part of input number.
DIMAG	-	imag part of input number.

printout:

see above.

HEAD24 **

HEAD24 prints a given string of 24 Hollerith characters. The first character need not be blank as the output format skips the first print position.

calling sequence:

```
CALL HEAD24(I HEAD)
```

input:

I HEAD - an array containing the character string to be printed.

printout:

see above.

PAGE **

PAGE initiates a page eject on the output form.

calling sequence:

```
CALL PAGE
```

printout:

see above.

STRLIN **

STRLIN prints a line consisting of 80 asterisks on the output form.

calling sequence:

CALL STRLIN

printout:

see above.

SKPLIN **

SKPLIN causes a desired number of lines to be skipped on the output form.

calling sequence:

```
CALL SKPLIN(NUMLIN)
```

INPUT:

NUMLIN - number of lines to be skipped.

printout:

see above.

PRPTBL **

PRPTBL prints the interconnection (or port) table.

calling sequence:

CALL PRPTBL

printout:

see above.

PRCTLG **

PRCTLG prints the master storage area catalog.

calling sequence:

```
CALL PRCTLG
```

printout:

see above.

UNPACK ***

UNPACK decodes the input string of Hollerith characters (until it reaches a $) to determine such items as sign conventions, accessible port number, network name, number of ports, and piece number if applicable.

calling sequence:

CALL UNPACK(IPORT, NIPORT, MCOUNT, N, ISIGNC, ISIGND, JPORT, NPORTS, NETNAM, IPC, NCHAR)

INPUT:

IPORT - array containing string of Hollerith characters.

NIPORT - maximum number of words in array IPORT.

input/output:

MCOUNT - counter for actual number of words used in IPORT.

N - counter for number of bytes in IPORT(I).

output:

ISIGNC - sign of C-matrix entry (dependent variable).

ISIGND - sign of D-matrix entry (independent variable).

JPORT - accessible port number.

NPORTS - network port number.

NETNAM - network name.

IPC - piece number if applicable.

NCHAR - counter for number of characters in NETNAM.

note: this routine calls the FLD function available in FORTRAN V on the Univac 1106 and 1108. For other systems it will need to be provided. Although more general on the Univac systems, the FLD function is used here only to extract the left most byte from a word.

calling sequence:

ICHAR(IF, IL, IWORD)

input:

IF - bit in IWORD to begin extracting (=0 for this case).

IL - bit in IWORD tc end extracting (=number of bits per byte for this case.

IWCRD - word from which bits are to be extracted.

BLKDTA *

BLKDTA is a BLOCK DATA routine used only for initializing certain quantities in COMMON.

Note: COMMON / CPT WRD / N BYT P W, N B P BYT must be set properly here for each particular computer.

(See Page A-2)

TIME **

TIME uses the subroutine LKCLKS (not provided in this package) to determine the present clock time and prints the elapsed time from the last call to TIME, as well as the total time since CALL LKCLKS (another routine not provided which initializes time in LKCLKS to 0).

calling sequence:

```
CALL TIME
```

note: LKCLKS returns the current clock time in seconds.

calling sequence:

```
CALL LKCLKS(T)
```

INPUT:

T - clock time (seconds)

printout:

see above.

Z1TOZ2 *

Z1TOZ2 finds the impedance (Z2) seen at output port given the A-form of the network matrix and the impedance (Z1) at input.

calling sequence:

CALL Z1TOZ2(NAME, NPC Z, DZ1R,DZ1I, DZ2R,DZ2I)

INPUT:

NAME	-	network name(unpacked).
NPCZ	-	piece number (0 for entire section).
DZ1R	-	real part of input impedance.
DZ1I	-	imag part of input impedance.

output:

DZ2R	-	real part of output impedance.
DZ2I	-	imag part of output impedance.

where:

Z2 = (A22*Z1-A12)/(-A21*Z1+A11)

<u>DCPCT2</u> **

DCPCT2 computes the force and velocity on the left of a piece (Fl,Vl) given the force and velocity on the right (Fr,Vr) and the 2x2 A matrix.

<u>calling sequence</u>:

```
CALL DCPCT2(NAME, N PC FV, DFRR,DFRI, DVRR,DVRI,
            DFLR,DFLI, DVLR,DVLI)
```

<u>INPUT</u>:

NAME	- network name(unpacked).
N PC FV	- piece number (0 for entire section).
DFRR	- real part of Fr.
DFRI	- imag part of Fr.
DVRR	- real part of Vr.
DVRI	- imag part of Vr.

<u>output</u>:

DFLR	- real part of Fl.
DFLI	- imag part of Fl.
DVLR	- real part of Vl.
DVLI	- imag part of Vl.

where:

Fl = A11*Fr + A12*Vr

Vl = A21*Fr + A22*Vr

FNDKRC **

FNDKRC computes the right handed decompaction matrix for a 3-3 mode ceramic stack (network type 11). (See Appendix D.)

calling sequence:

```
CALL FNDKRC(IZ C3S, IN ZC3, IKR3C)
```

input:

- IZ C3S - master storage location for C3S matrix.
- IN ZC3 - master storage location for single piece matrix.
- IKR3C - master storage location for storing right handed decompaction matrix.

SRCHBC **

SRCHBC performs the Search process as described in Appendix D.

calling sequence:

```
CALL SRCHBC(IA5S, IB4C, IC3S, IR3C, IM2S, IS2S)
```

input:

IA5S	- master storage location for matrix A5S.
IB4C	- master storage location for matrix B4C.
IC3S	- master storage location for matrix C3S.
IR3C	- master storage location for matrix R3C.
IM2S	- master storage location for matrix M2S.
IS2S	- master storage location for matrix S2S.

MINCHK ***

MINCHK compares two input numbers to find the minimum. If a new minimum is found, then a new identification subscript is stored, and a flag is set.

calling sequence:

```
CALL MINCHK(DNEW, DMIN, INEW, IMIN, MINFND)
```

INPUT:

DNEW - new value.

input/output:

DMIN - minimum.

input:

INEW - identification subscript corresponding to DNEW.

input/output:

IMIN - identification subscript corresponding to DMIN.

output:

MINFND - flag to indicate that new minimum was found.

logic:

If (DNEW .LT. DMIN) then DMIN=DNEW, IMIN=INEW, MINFND=1

otherwise MINFND = 0

MAXCHK ***

MAXCHK compares two input numbers to find the maximum. If a new maximum is found, then a new identification subscript is stored, and a flag is set.

calling sequence:

```
CALL MAXCHK(DNEW, DMAX, INEW, IMAX, MAXFND)
```

input:

DNEW - new value.

input/output:

DMAX - maximum.

input:

INEW - identification subscript corresponding to DNEW.

input/output:

IMAX - identification subscript corresponding to DMAX.

output:

MAXFND - flag to indicate that new maximum was found.

logic:

If (DNEW .GT. DMAX) then DMAX=DNEW, IMAX=INEW, MAXFND=1

otherwise MAXFND = 0

CMPZS **

CMPZS is used in conjunction with the SEARCH procedure (Appendix D) to compute and store the self impedance. This routine should be modified by the user when a non-zero self impedance is required.

calling sequence:

CALL CMPZS

printout:

As written this routine prints ZSELF=0 only once in a run.

PREPZV *

PREPZV reads from cards or card images on magnetic tape a heading card followed by an array of radiation impedances. The array is scaled by desired scale factors and written onto an auxiliary storage unit for use later in the calculations.

calling sequence:

```
CALL PREPZV(NARRAY, IFARAY, INZVUN, IOUTUN, FSCALE,ZSCALE,VSCALE)
```

input:

- NARRAY - array number.
- IFARAY - frequency at which the radiation impedances were generated.
- INZVUN - logical input unit number.
- IOUTUN - logical output unit number (not equal to INZVUN).
- FSCALE - scale factor for IFARAY.
- ZSCALE - scale factor for radiation impedances.
- VSCALE - scale factor for velocities associated with the impedances.

heading card input format:

FORMAT(A4,A2, I4, I5, 16A4)

columns 2- 6 contain ARRAY (Hollerith string)

columns 7-10 contain array number

columns 11-15 contain number of impedances to read in

columns 16-79 contain heading information

data card input format:

FORMAT(2I3, I5, 3I3, 2E15.8, 2E15.8)

SEE LDZRVR for arguments

printout:

prints the input card information.

FNDFZV ***

FNDFZV reads the array of radiation impedances that has previously been read in by PREPZV for the purpose of checking for proper array number and frequency.

calling sequence:

CALL FNDFZV(IF SWP)

input:

IF SWP - not presently used by the routine. However it is the value of the frequency (from the Search process frequency sweep) in the event that the user wants to change the array of radiation impedances as a function of frequency.

LDZRVR ***

LDZRVR reads a card image containing radiation impedance information used in the Search process.

calling sequence:

```
CALL LDZRVR
```

modified card image format:

```
FORMAT(2I4,I5,3I3, 2(E14.7,E13.7))
```

I1	- row number of element.
J1	- column number of element.
IF	- frequency for radiation impedance.
ICODE	- identification code supplied by user.
IBETAS	- azimuth
IGAMAS	- depression elevation.
ZR	- real part of radiation impedance.
ZI	- imag part of radiation impedance.
VR	- real part of velocity.
VI	- imag part of velocity.

SRMIDB *

SRMIDB performs the single reactor midband logic as described in the Search process of Appendix D.

calling sequence:

CALL SRMIDB(DFP, L MX MN, L EC IC, L FLG SP, DLRM, DLQM)

input:

DFP	-	frequency
L MX MN	-	flag specifying either to maximize or minimize. = 3HMAX to maximize ≠ 3HMAX to minimize
L EC IC	-	specifies whether |Zec| or |Zic| is to be extremized. = 2HEC to extremize |Zec| ≠ 2HEC to extremize |Zic|
L FLG SP	-	specifies either series or parallel reactor. = 1HS for series ≠ 1HS for parallel
DLRM	-	series resistance of the reactor
DLQM	-	reactor quality factor

printout:

values of input and output (controlled by COMMON / PRT OFF / NO PRT).

LDAM2S **

LDAM2S computes and stores the A-form of the M2S network(matching network) used in the Search procedure (Appendix D).

calling sequence:

CALL LDAM2S

printout:

A M2S matrix (controlled by COMMON / PRT OFF / NO PRT).

CMPGAM **

CMPGAM is used in the Search procedure discussed in Appendix D to compute (1) voltage-velocity control impedance, Zec, (2) current-velocity control impedance, Zic, (3) GAMMAec = Zself + Zic, (4) GAMMAic = Zself + Zic where Zself is the self impedance of the element.

calling sequence:

CALL CMPGAM(IN A A2S)

input:

IN A A2S - master storage location of the A-form matrix for the A2S network.

printout:

A S2R matrix and GAMMA ec, GAMMA ic (controlled by COMMON / PRT OFF / NO PRT).

FSRCH *

FSRCH searches out performance variables for a transducer over a specified frequency range with an input array of of radiation impedances. The method used is discussed in Appendix D.

calling sequence:

```
CALL FSRCH(IF FRST, IF LAST, IF DELT,
           I OUT OP, I UNIT T, IHLBL1, IHLBL2)
```

input:

IF FRST - initial frequency.

IF LAST - maximum frequency.

IF DELT - frequency increment.

I OUT OP - output options as discussed in Appendix D.

I UNIT T - logical unit number for output to be saved (=0 if not desired).

IHLBL1 - first word of a label for output.

IHLBL2 - second word of a label for output.

printout:

a page for each frequency and its associated performance variables.

RLIMMG **

RLIMMG provides the functional relationship of the dependent variable used primarily by subroutine FMFN. The routine should be changed for different functional relationships. As programmed the routine finds the admittance Yc of the DD network for Run 80006 in Appendix E.

calling sequence:

CALL RLIMMG(DX, DRL, DIM, DMG)

input:

DX	-	independent variable.

output:

DRL	-	real part of dependent variable.
DIM	-	imag part of dependent variable.
DMG	-	magnitude of dependent variable.

printout:

above values (controlled by COMMON / C FMN PR / I FMN PR
where I FMN PR = 0 for no print).

FMFN *

FMFN computes the maximum and/or minimum of a function(evaluated RLIMMG) given an initial guess. The routine utilizes a pole-z technique which is further refined by a parabolic fit.

calling sequence:

    CALL FMFN(DFMGES, DXM, DYMM, DXN, DYNN)

input:

DFMGES - initial guess for independent variable, DXM.

output:

DXM - value of independent variable at maximum of dependent variable.

DYMM - relative maximum of dependent variable in region DFMGES.

DXN - value of independent variable at minimum of dependent variable.

DYNN - relative minimum of dependent variable in region DFMGES.

additional input options can be set via

    COMMON / CMN FMN / MIN SKP, MAX SKP, N1 POL 0

MIN SKP - flag
= 1 will not find minimum of the function.
≠ 1 will find minimum of the function.

MAX SKP - flag
= 1 will not find maximum of the function.
≠ 1 will find maximum of the function.

N1 POL 0 - flag controlling pole-zero technique.
= 1 apply pole-zero once
≠ 1 apply pole zero twice

note: all three flags are set to 0 as a default condition in BLK DTA.

POLEO ***

POLEO is used to find the frequency at which a relative maximum and a relative minimum of the complex admittance function occurs given three frequencies for the function to be evaluated. This routine has been designed to apply particularily to piezoelectric electromechanical systems. The admittance, Yc, of such systems with widely separated resonant behavior can be approximated at frequencies well below the second resonance by Y(f) = f(f-b)/(f-c). (note: for magnetostrictive systems a similar type of treatment will apply, but Y must denote complex impedance instead of complex admittance.)

calling sequence:

```
CALL PCLEO(DX1, DX2, DX3, DXM, DXN)
```

input:

DX1	- first value of the independent variable.
DX2	- second value of the independent variable.
DX3	- third value of the independent variable.

output:

DXM	- value of the independent variable at which the dependent variable is a maximum.
DXN	- value of the independent variable at which the dependent variable is a minimum.

method:

The technique was developed from the idea that the frequency poles and zeros determine the admittance as a function of frequency.

Y(f) = (A(f-a1)(f-a2)(f-a3)...)/((f-b1)(f-b2)(f-b3)...)

where a1,a2,a3,...,b1,b2,... are complex constants.

For this case Y(f)=0 if f=0. Therefore, a1 is set to 0. It may also be assumed that only a small portion of the complex frequency affects the function so that only one pole and one zero need be considered, i.e.

Y(f) = f(f-b)/(B(f-c))

or

Y(f)/f = B + B(c-b)/(f-c)

$Y(f)/f = B + D/(f-c)$.

Given the value of the admittance function, $Y(f)$, at three frequencies $(f1,f2,f3)$ allows a solution for the constants B, D, and c. The solutions are

$$B = -D/(f1-c) + Y1$$

$$D = (Y1-Y2)/(1/(f1-c)-1/(f2-c))$$

$$c = (f1(f2-f3)Y1 + f2(f3-f1)Y2 + f3(f1-f2)Y3) / ((f2-f3)Y1 + (f3-f1)Y2 + (f1-f2)Y3)$$

$$b = c - D/B$$

Therefore, the value of b gives the frequency at which a minimum occurs, and c gives the frequency at which the maximum occurs.

PRBFIT ***

PRBFIT performs a parabolic fit to the dependent variable at the input value of the independent variable to determine either a maximum or minimum point. The dependent variable functional relationship is described through RLDMG.

calling sequence:

```
CALL PRBFIT(DX, DYMG)
```

input/output:

DX - independent variable input value which will be modified to give a value closer to the actual maximum or minimum.

output:

DYMG - maximum or minimum value of the dependent variable corresponding to DX.

method:

Assume that a parabolic fit to the function $y = f(x)$ is desired at the point xm. Define

eps = xm * 1.E-4

x1 = xm - eps

x2 = xm

x3 = xm + eps

and determine f(x1), f(x2), f(x3).

Calculate

$$\text{eps prime} = (\text{eps}/2)(|f(x1)| - |f(x3)|) \,/\, (|f(x1)| - 2|f(x2)| + |f(x3)|)$$

and

xm = x2 + eps prime

If $||f(xm)| - |f(x2)|| \,/\, |f(xm)|$ is less than the error tolerance, then stop. Otherwise do the following replacements and cycle again:

eps = eps prime

x1 = x2

x2 = xm

x3 = xm + eps.

FNDPRM *

FNDPRM iterates on the given ceramic parameters until agreement with experimental results(i.e.,FM, FN, YM, YN, CLO, CLOM) is obtained within a certain tolerance. (See Appendix E.)

calling sequence:

```
CALL FNDPRM(C NAME, FM, FN, YM, YN, CLO, CLOM, FLO, MAX)
```

input:

C NAME	- name of the ceramic section.
FM	- frequency where admittance is a maximum.
FN	- frequency where admittance is a minimum.
YM	- maximum admittance.
YN	- minimum admittance.
CLO	- the electrical input parallel capacitance at the frequency FLO.
CLOM	- the dissipation factor at frequency FLO.
FLO	- frequency which is below FM and near the lower frequency limit of the actual transducer operating frequency.
MAX	- max number of iterations.

printout:

see writeup for subroutine PRTPRM.

FNDFDP ***

FNDFDP computes the values to compare with experimental data in the Find Parameters procedure described in Appendix E.

calling sequence:

CALL FNDFDP

LDBCOL ***

LDBCOL loads a column of the Find Parameters matrix. (See Appendix E.)

calling sequence:

```
CALL LDBCOL(J COL, N CAP)
```

input:

J COL - column number to be loaded.

N CAP - total number of rows in matrix.

PRTPRM ***

PRTPRM prints the output from the Find Parameters procedure. (See Appendix E.)

calling sequence:

```
CALL PRTPRM
```

printout:

prints at each iteration the experimental values, the new values using the newly computed parameters, and the relative errors.

APPENDIX B

IMPLEMENTED NETWORK TYPES

Table 1 summarizes the networks presently implemented in the program. For each network the input data, sign conventions, and equations programmed are included in the descriptions which follow:

TABLE 1. Summary of Network Types.

(* indicates frequency dependence)

Type		Description	Input Data
1	*	Straight Piece	NAME,RHO,A,ID,OD,L,Cr,Ci,Cm
2	*	Conical Piece	NAME,RHO,A1,ID1,OD1,A2,ID2, OD2,L,Cr,Ci,Cm
4		Ideal Transformer	NAME,TURNS RATIO
5		Arbitrary n by n Matrix	NAME,ZIJr,ZIJi
7	*	Rational Polynomial in Frequency	NAME,FACTOR,IFORM,NSYMFG, coefficients
8		Voltage to Voltage Converter	NAME,ZI,ZO,ALPHA
9		Voltage to Current Converter	NAME,ZI,ZO,BETA
11	*	3-3 Mode Ceramic Stack	NAME,N,RHO,A,ID,OD,L, E33Tr,E33Ti,E33Tm, G33r,G33i,G33m, S33Dr,S33Di,S33Dm
14	*	3-1 Mode Ceramic Thin Bar	NAME,RHO,T,W,L, E33Tr,E33Ti,E33Tm, G31r,G31i,G31m, S11Er,S11Ei,S11Em
15	*	3-1 Mode Ceramic Tube	NAME,RHO,ID,OD,L, E33Tr,E33Ti,E33Tm, G31r,G31i,G31m, S11Er,S11Ei,S11Em

20	*	Linear Transformer	NAME,RP,LP,RO,LO,RS,LS,PHI
21	*	Series Impedance	NAME,RS,LS,CS
22	*	Parallel Impedance	NAME,RS,LS,CS
24	*	Series Admittance	NAME,RP,LP,CP
25	*	Parallel Admittance	NAME,RP,LP,CP
26	*	Linear Model of a Differential Input Operational Amplifier	NAME,R1,C1,R2,C2,RD,CD,R3,L3, AO, OMEGA1,OMEGA2,OMEGA3

TYPE 1: STRAIGHT PIECE (non-ceramic)

Input Parameters:

A = Area (m^2)

L = Length (m)

c = Sound Velocity = $c_r\,(1+jc_m)$ (m/sec)

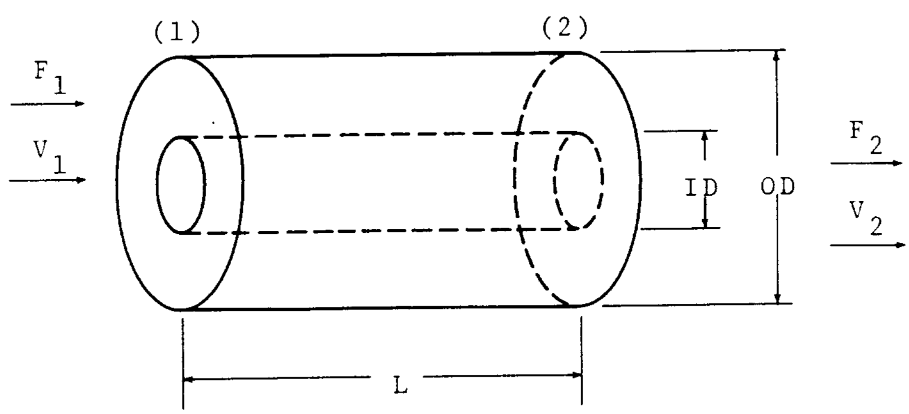
ρ = Density (kg/m^3)

OD = Outer Diameter (m) } when applicable

ID = Inner Diameter (m) } when applicable

f = Frequency (Hz)

$\omega = 2\pi f$



Computed Parameters:

$k = \omega/c$

$A_{11} = A_{22} = \cos(kL)$ $\qquad Z_{11} = -j\rho cA\cot(kL)$

$A_{12} = j\rho cA\sin(kL)$ $\qquad Z_{12} = -Z_{21} = j\rho cA\csc(kL)$

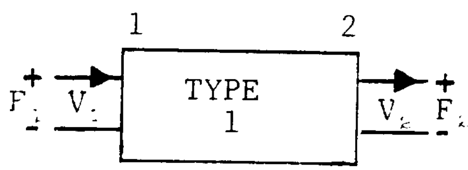
$A_{21} = j(\sin(kL))/(\rho cA)$ $\qquad Z_{22} = j\rho cA\cot(kL)$

Note that

$$\begin{bmatrix} F_1 \\ F_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} \qquad |A| = 1 \quad ,$$

and

$$\begin{bmatrix} F_1 \\ V_1 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} F_2 \\ V_2 \end{bmatrix} \quad .$$



TYPE 2: CONICAL PIECE (non-ceramic)

Input Parameters:

A_1 = Area at (1) (m^2)

A_2 = Area at (2) (m^2)

L = Length (m)

c = Sound Velocity = c_r (1+jcm) (m/sec)

ρ = Density (kg/m^3)

OD_1 = Outer Diameter at (1) (m)

OD_2 = Outer Diameter at (2) (m)

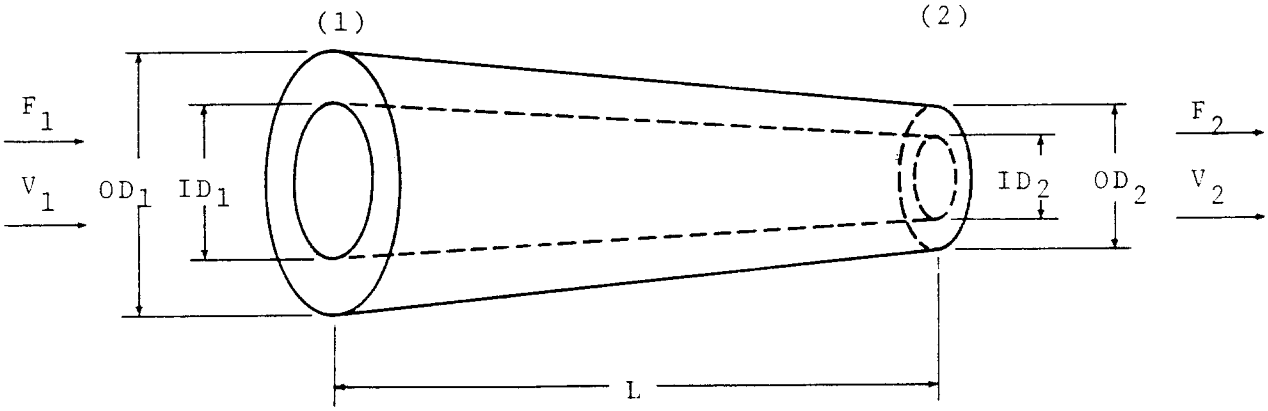
ID_1 = Inner Diameter at (1) (m)

ID_2 = Inner Diameter at (2) (m)

(OD and ID: when applicable)

f = Frequency (Hz)

ω = $2\pi f$



Computed Parameters:

$$k = \omega/c$$

$$A_{11} = \sqrt{A_1/A_2}\,[\cos(kL) - \sin(kL)/(kL)] + \sin(kL)/kL$$

$$A_{12} = j\rho c[1/(kL)(\sin(kL)/(k\ell) + \cos(kL))(\sqrt{A_1} - \sqrt{A_2})^2 + \sqrt{A_1A_2}\sin(kL)]$$

$$A_{21} = j\sin(kL)/(\rho c\sqrt{A_1A_2})$$

$$A_{22} = \sqrt{A_2/A_1}\,[\cos(kL) - \sin(kL)/(kL)] + \sin(kL)/(kL)$$

$$Z_{11} = -j\rho c A_1\ [\cot(kL) - 1/(kL)] - j\rho c\sqrt{A_1 A_2}\ [1/(kL)]$$

$$Z_{12} = -Z_{21} = j\rho c\sqrt{A_1 A_2}\ \csc(kL)$$

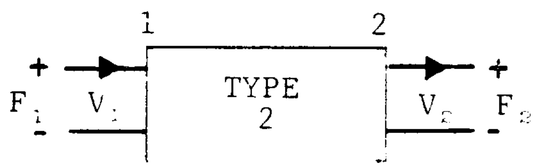
$$Z_{22} = j\rho c A_2\ [\cot(kL) - 1/(kL)] + j\rho c\sqrt{A_1 A_2}\ [1/(kL)]$$

Note that

$$\begin{bmatrix} F_1 \\ F_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} .$$

and

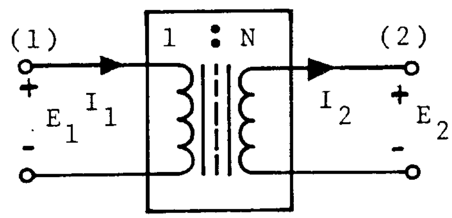
$$\begin{bmatrix} F_1 \\ V_1 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} F_2 \\ V_2 \end{bmatrix} \qquad |A| = 1 .$$



TYPE 4: IDEAL TRANSFORMER

Input Parameters:

N = Secondary/Primary Turns Ratio



Computed Parameters:

$A_{11} = 1/N$

$A_{12} = 0$

$A_{21} = 0$

$A_{22} = N$

NOTE: THE Z-FORM DOES NOT EXIST
THE Y-FORM DOES NOT EXIST.

If N=1, [A] = Unit Matrix,

where

$$\begin{bmatrix} E_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} E_2 \\ I_2 \end{bmatrix} .$$

TYPE 5: Arbitrary n by n Matrix

Input Parameters: List of complex numbers for elements of an n by n matrix.

TYPE 7: RATIONAL POLYNOMIAL IN FREQUENCY

Input Parameters:

FACTOR = scale factor for input coefficients

IFORM = flag for form of input matrix

NSYMFG = flag for symmetry of input matrix

C_{nij} = complex coefficients for numerator polynomial (n=0, . . . , N)

d_{mij} = complex coefficients for denominator polynomial (m=0, 1, . . . , M)

N = order of numerator polynomial

M = order of denominator polynomial

f = frequency (Hz)

where:

i, j = 1, 2, . . . , K

K = the number of network ports

Computed Parameters:

$$Zij = \frac{\sum_{n=0}^{N} C_{nij} * f^n}{\sum_{m=0}^{M} d_{mij} * f^m}$$

Note: For definitions of IFORM and NSYMFG, see Appendix A subroutine writeup for LD DT 7.

TYPE 8: VOLTAGE TO VOLTAGE CONVERTER (can be used as Amplifier model)

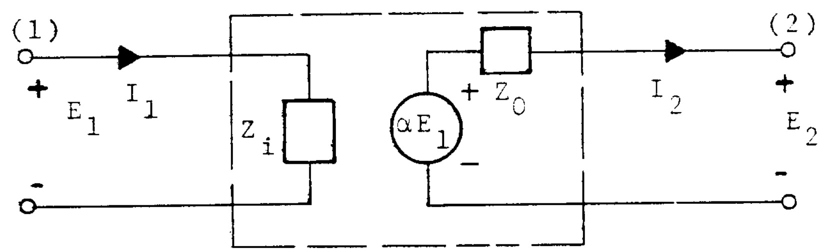
Input Parameters:

Z_i = Input impedance of amplifier (ohms)

Z_O = Output impedance (ohms)

α = Voltage gain

Note: All three parameters are complex and a function of frequency.



Computed Parameters:

$A_{11} = 1/\alpha$ $\qquad$ $Z_{11} = Z_i$

$A_{12} = Z_O/\alpha$ $\qquad$ $Z_{12} = 0$

$A_{21} = 1/(\alpha Z_i)$ $\qquad$ $Z_{21} = \alpha Z_i$

$A_{22} = Z_O/(\alpha Z_i)$ $\qquad$ $Z_{22} = -Z_O$

Note that

$$\begin{bmatrix} E_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} E_2 \\ I_2 \end{bmatrix} , \qquad |A| \neq 1$$

and

$$\begin{bmatrix} E_1 \\ E_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} .$$

$Y = Z^{-1}$

TYPE 9: VOLTAGE TO CURRENT CONVERTER
(can be used as Norton Amplifier Model)

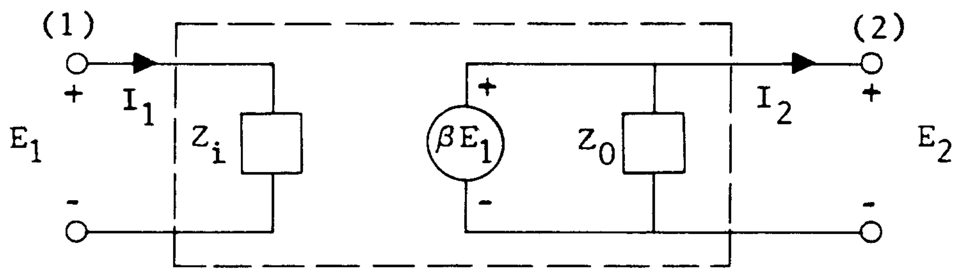
Input Parameters:

Z_i = Input impedance of amplifier (ohms)

Z_O = Output impedance (ohms)

β = Voltage to current gain (transconductance, Mhos)

All three parameters are complex and a function of frequency.



Computed Parameters:

$A_{11} = 1/(\beta Z_O)$ $\qquad Z_{11} = Z_i$

$A_{12} = 1/\beta$ $\qquad Z_{12} = 0$

$A_{21} = 1/(\beta Z_i Z_O)$ $\qquad Z_{21} = \beta Z_i Z_O$

$A_{22} = 1/(\beta Z_i)$ $\qquad Z_{22} = -Z_O$

Note that

$$\begin{bmatrix} E_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} E_2 \\ I_2 \end{bmatrix}, \qquad |A| \neq 1$$

and

$$\begin{bmatrix} E_1 \\ E_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}.$$

$Y = Z^{-1}$

TYPE 11: 3-3 MODE CERAMIC STACK

Input Parameters:

ρ = Density (kg/m^3)

A = Area of poled surface (m^2)

L = Piece length (m)

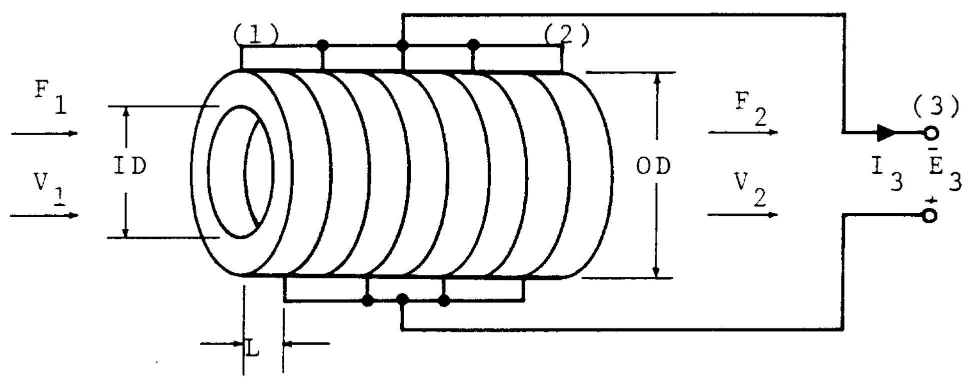
N = Number of pieces

OD = Outer diameter
ID = Inner diameter
} when applicable

E_{33}^T = E33TR (1 - jE33TM)
g_{33} = G33R (1 - jG33M)
s_{33}^D = S33DR (1 - jS33DM)
} Ceramic stack parameters in RMKSAa Units

f = Frequency (Hz)

ω = $2\pi f$



Computed Parameters:

$$c = \sqrt{1/(\rho s_{33}^D)}$$

$$k = \omega/c$$

ϵ_O = Permittivity of vacuum (8.8542×10^{-12})

$$\beta_{33}^{LC} = (g_{33})^2/s_{33}^D + 1/(\epsilon_O E_{33}^T)$$

$$C_O = A/(L\beta_{33}^{LC})$$

$$\Phi = g_{33}C_O/s_{33}^D$$

$$z_O = \Phi/(j\omega C_O)$$

$$z_O^C = z_O/N$$

$$Z_{22}^S = j\rho cA\cot(kL) + \Phi z_O = -Z_{11}^S$$

$$Z_{12}^S = j\rho cA\csc(kL) + \Phi z_O = -Z_{21}^S$$

$$\alpha = \cosh^{-1}(Z_{22}^S/Z_{12}^S)$$

$$Z_O = -Z_{12}^S \sinh(\alpha)$$

$$K_{33} = g_{33}\sqrt{\frac{1}{\beta_{33}^{LC}\, s_{33}^D}}$$

$$Z_{11} = Z_O\coth(N\alpha) + \Phi z_O^C$$

$$Z_{12} = -Z_O\operatorname{csch}(N\alpha) - \Phi z_O^C$$

$$Z_{13} = z_O^C$$

$$Z_{21} = -Z_{12}$$

$$Z_{22} = -Z_{11}$$

$$Z_{23} = Z_{13}$$

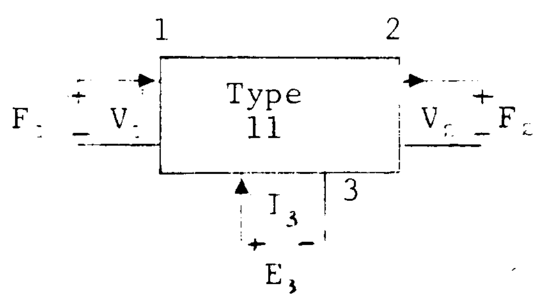
$$Z_{31} = Z_{13}$$

$$Z_{32} = -Z_{13}$$

$$Z_{33} = z_O^C/\Phi$$

Note that

$$\begin{bmatrix} F_1 \\ F_2 \\ E_3 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} & Z_{13} \\ Z_{21} & Z_{22} & Z_{23} \\ Z_{31} & Z_{32} & Z_{33} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ I_3 \end{bmatrix}$$



TYPE 14: 3-1 MODE CERAMIC THIN BAR

Input Parameters:

ρ = density (kg/m^3)

t = thickness (m)

w = foil width (m)

L = length (m)

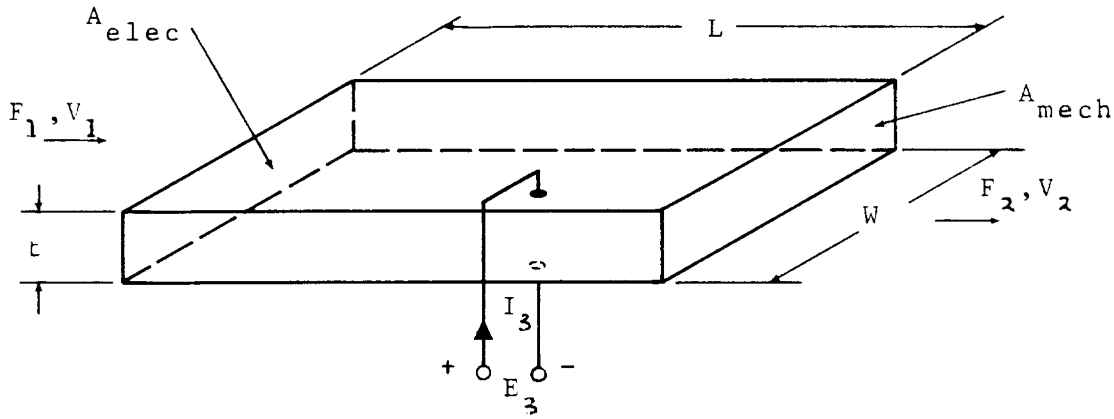
E_{33}^T = E33TR (1 - jE33TM)

g_{31} = G31R (1 - jG31M)

s_{11}^E = S11ER (1 - jS11EM)

f = frequency (Hz)

$\omega = 2\pi f$



COMPUTED PARAMETERS:

$$c = \frac{1}{\sqrt{\rho\, s_{11}^E}}$$

$$k = \omega / c$$

$$\epsilon_O = 8.8542 \times 10^{-12}$$

$$D_{31} = E_{33}^T \times \epsilon_O \times g_{31}$$

$$(k_{31})^2 = g_{31} \times D_{31} / s_{11}^E$$

$$A_{mech} = t \times w$$

$$A_{elec} = L \times w$$

$$\text{mass} = \rho \times A_{mech} \times L$$

$$C_O = \left(\frac{A_{elec}}{t}\right) \times \epsilon_O \times E^T_{33} \times (1 - K^2_{31})$$

$$\Phi = A_{elec} \times D_{31}/(s^E_{11} \times L)$$

$$Z_{33} = 1/(j\omega C_O)$$

$$z_O = \Phi \times Z_{33}$$

$$Z^S_{11} = -j\rho C \times A_{mech}/\tan(k \times L) = -Z^S_{22}$$

$$Z^S_{12} = j\rho C \times A_{mech}/\sin(k \times L) = -Z^S_{21}$$

$$Z_{11} = Z^S_{11} + \Phi z_O = -Z_{22}$$

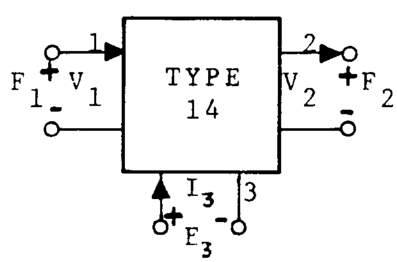
$$Z_{12} = Z^S_{12} - \Phi z_O = -Z_{21}$$

$$Z_{13} = z_O = Z_{31} = Z_{23}$$

$$Z_{32} = -Z_{13}$$

Note that

$$\begin{bmatrix} F_1 \\ F_2 \\ E_3 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} & Z_{13} \\ Z_{21} & Z_{22} & Z_{23} \\ Z_{31} & Z_{32} & Z_{33} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ I_3 \end{bmatrix} .$$



TYPE 15: 3-1 MODE CERAMIC TUBE

Input Parameters:

ρ = density (kg/m^3)

ID = inner diameter (m)

OD = outer diameter (m)

L = length (m) (all foiled)

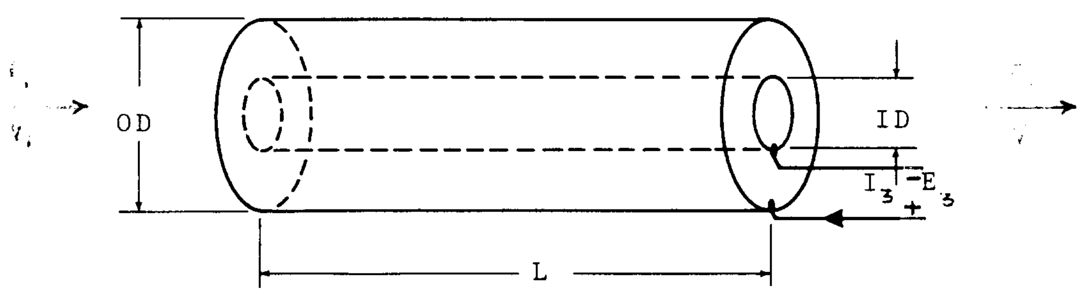
E^T_{33} = E33TR (1 - jE33TM)

g_{31} = G31R (1 - jG31M)

s^E_{11} = S11ER (1 - jS11EM)

f = frequency

$\omega = 2\pi f$



COMPUTED PARAMETERS:

$$c = \frac{1}{\rho \times s^E_{11}}$$

$$k = \omega / c$$

$$\epsilon_O = 8.8542 \times 10^{-12}$$

$$D_{31} = E^T_{33} \times \epsilon_O \times g_{31}$$

$$(K_{31})^2 = g_{31} \times D_{31} / s^E_{11}$$

$$A_{mech} = (OD + ID)(OD - ID) \times \pi/4$$

$$A_{elec} = (OD + ID) \times L \times \pi/2$$

$$\text{mass} = \rho \times A_{mech} \times L$$

$$C_O = 2\pi L/\ell n\,(OD/ID) \times \epsilon_O \times E_{33}^T \times (1 - K_{31}^2)$$

$$\Phi = A_{elec} \times D_{31}/(s_{11}^E \times L)$$

$$Z_{33} = 1/j\omega C_O)$$

$$z_O = \Phi \times Z_{33}$$

$$Z_{11}^S = j\rho c \times A_{mech}/\tan(k \times L) = -Z_{22}^S$$

$$Z_{12}^S = j\rho c \times A_{mech}/\sin(k \times L) = -Z_{21}^S$$

$$Z_{11} = Z_{11}^S + \Phi z_O = -Z_{22}$$

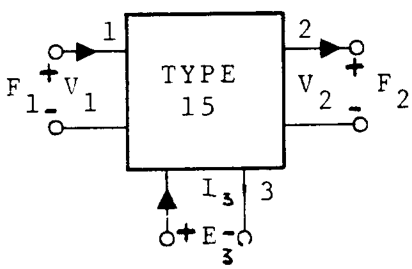
$$Z_{12} = Z_{12}^S - \Phi z_O = -Z_{21}$$

$$Z_{13} = z_O = Z_{31} = Z_{23}$$

$$Z_{32} = -Z_{13}$$

Note that

$$\begin{bmatrix} F_1 \\ F_2 \\ E_3 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} & Z_{13} \\ Z_{21} & Z_{22} & Z_{23} \\ Z_{31} & Z_{32} & Z_{33} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ I_3 \end{bmatrix}$$



TYPE 20: LINEAR TRANSFORMER

Input Parameters:

Φ = Turns ratio; secondary/primary

R_P, R_S = Copper losses in primary and secondary (ohms)

R_O = Core loss (ohms)

L_P, L_S = Winding inductances in primary and secondary (H)

L_O = Magnetizing inductance (H)

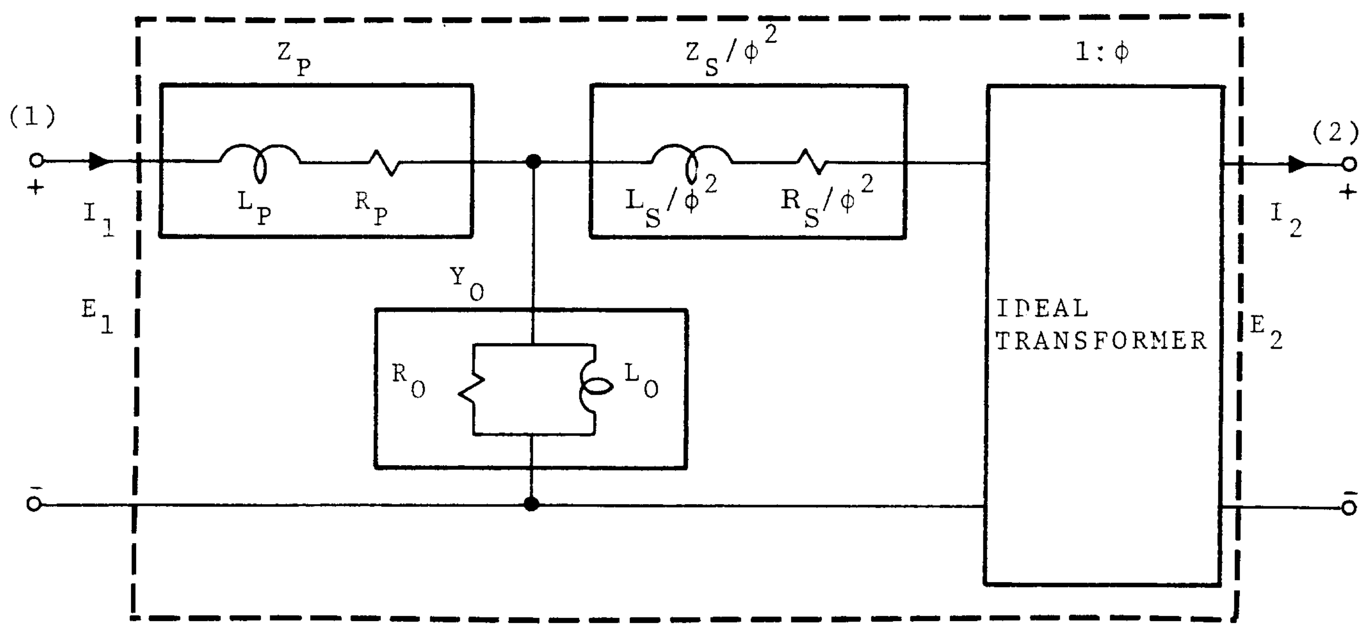
Z_P = Primary impedance = $R_P + j\omega L_P$ (ohms)

Y_O = Shunt Admittance $= \dfrac{1}{R_O} + \dfrac{1}{j\omega L_O}$ (mhos)

Z_S = Secondary impedance = $R_S + j\omega L_S$ (ohms)

f = Frequency (Hz)

$\omega = 2\pi f$



Computed Parameters:

$$Z_P = R_P + j\omega L_P$$

$$Z_O = 1/Y_O \qquad\qquad Z_{SAP} = Z_S/\Phi^2$$

$$Z_S = R_S + j\omega L_S$$

$$Z_{11} = Z_P + Z_O \qquad\qquad A_{11} = [1 + Z_P Y_O]/\Phi$$

$$Z_{12} = -\Phi Z_O \qquad\qquad A_{12} = \Phi[Z_{SAP} + Z_P + Z_{SAP} Z_P Y_O]$$

$$Z_{21} = -Z_{12} \qquad\qquad A_{21} = Y_O/\Phi$$

$$Z_{22} = -[\Phi^2 Z_O + Z_S] \qquad\qquad A_{22} = \Phi[1 + Z_{SAP} Y_O]$$

Note that

$$\begin{bmatrix} E_1 \\ E_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} ,$$

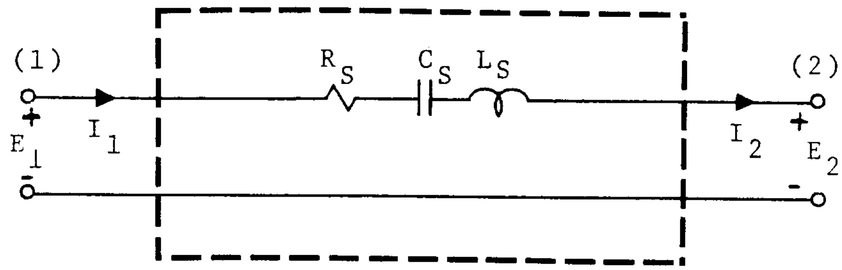
and

$$\begin{bmatrix} E_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} E_2 \\ I_2 \end{bmatrix} . \qquad |A| = 1$$

TYPE 21: SERIES IMPEDANCE

Input Parameters:

R_S = Resistance (ohms)
L_S = Inductance (H)
C_S = Capacitance (F)
f = Frequency (Hz)
$\omega = 2\pi f$



Computed Parameters:

$$Z_S = R_S + j\left(\omega L_S - \frac{1}{\omega C_S}\right)$$

Let

$C_S = 10^{30}$ for no capacitor,
$L_S = 0$ for no inductor,

and

$R_S = 0$ for no resistor.

Then

$A_{11} = 1$,
$A_{12} = Z_S$,
$A_{21} = 0$,

and

$A_{22} = 1$,

where

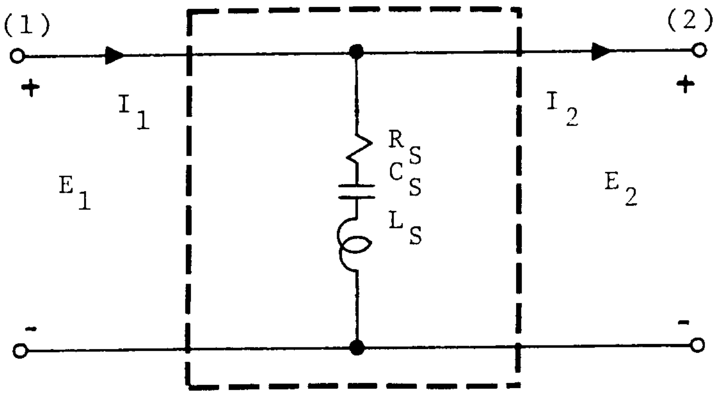
$$\begin{bmatrix} E_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} E_2 \\ I_2 \end{bmatrix} . \qquad |A| = 1$$

NOTE: THE Z-FORM DOES NOT EXIST

TYPE 22: PARALLEL IMPEDANCE

Input Parameters:

R_S = Resistance (ohms)
L_S = Inductance (H)
C_S = Capacitance (F)
f = Frequency (Hz)
$\omega = 2\pi f$



Computed Parameters:

$$Z_S = R_S + j\left(\omega L_S - \frac{1}{\omega C_S}\right)$$

Let

$C_S = 10^{30}$ for no capacitor,

$L_S = 0$ for no inductor,

and

$R_S = 0$ for no resistor.

Then

$A_{11} = 1,$	$Z_{11} = Z_S,$	
$A_{12} = 0,$	$Z_{12} = -Z_S,$	$\vert A \vert = 1$
$A_{21} = 1/Z_S,$	$Z_{21} = Z_S,$	$\vert Z \vert = 0$
$A_{22} = 1,$	$Z_{22} = -Z_S,$	

where

$$\begin{bmatrix} E_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} E_2 \\ I_2 \end{bmatrix},$$

and

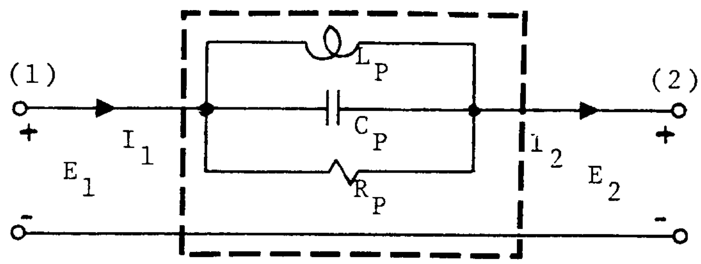
$$\begin{bmatrix} E_1 \\ E_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}.$$

NOTE: THE Y-FORM DOES NOT EXIST

TYPE 24: SERIES ADMITTANCE

Input Parameters:

R_P = Resistance (ohms)
L_P = Inductance (H)
C_P = Capacitance (F)
f = Frequency (Hz)
$\omega = 2\pi f$



Computed Parameters:

$$Y_P = \frac{1}{R_P} + j\left(\omega C_P - \frac{1}{\omega L_P}\right)$$

Let

$R_P = 10^{30}$ for no resistor,
$L_P = 10^{30}$ for no inductor,

and

$C_P = 0$ for no capacitor.

Then,

$A_{11} = 1$

$A_{12} = \frac{1}{Y_P}$

$A_{21} = 0$

and

$A_{22} = 1$.

Note that

$$\begin{bmatrix} E_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} E_2 \\ I_2 \end{bmatrix} . \qquad |A| = 1$$

NOTE: Z-FORM DOES NOT EXIST

TYPE 25: PARALLEL ADMITTANCE

Input Parameters:

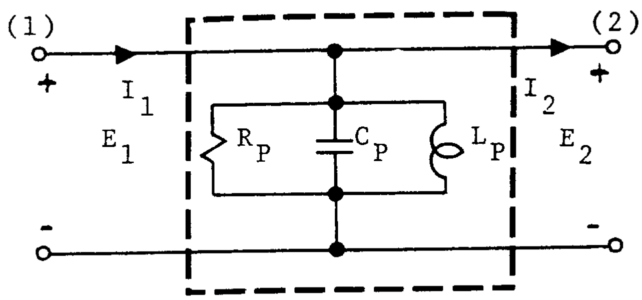
R_P = Resistance (ohms)

L_P = Inductance (H)

C_P = Capacitance (F)

f = frequency (Hz)

$\omega = 2\pi f$



Computed Parameters:

$$Y_P = \frac{1}{R_P} + j\left(\omega C_P - \frac{1}{\omega L_P}\right)$$

Let

$R_P = 10^{30}$ for no resistor,

$L_P = 10^{30}$ for no inductor,

and

$C_P = 0$ for no capacitor.

Then,

$A_{11} = 1$,

$A_{12} = 0$,

$A_{21} = Y_P$,

and

$A_{22} = 1$,

where

$$\begin{bmatrix} E_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} E_2 \\ I_2 \end{bmatrix} . \qquad |A| = 1$$

NOTE: Y-FORM DOES NOT EXIST

TYPE 26: LINEAR MODEL OF A DIFFERENTIAL INPUT OPERATIONAL AMPLIFIER

Input Parameters:

R_1 = Input resistance (ohms)

C_1 = Input capacitance (F)

R_2 = Input resistance (ohms)

C_2 = Input capacitance (F)

R_D = Differential input resistance (ohms)

C_D = Differential input capacitance (F)

R_3 = Output resistance (ohms)

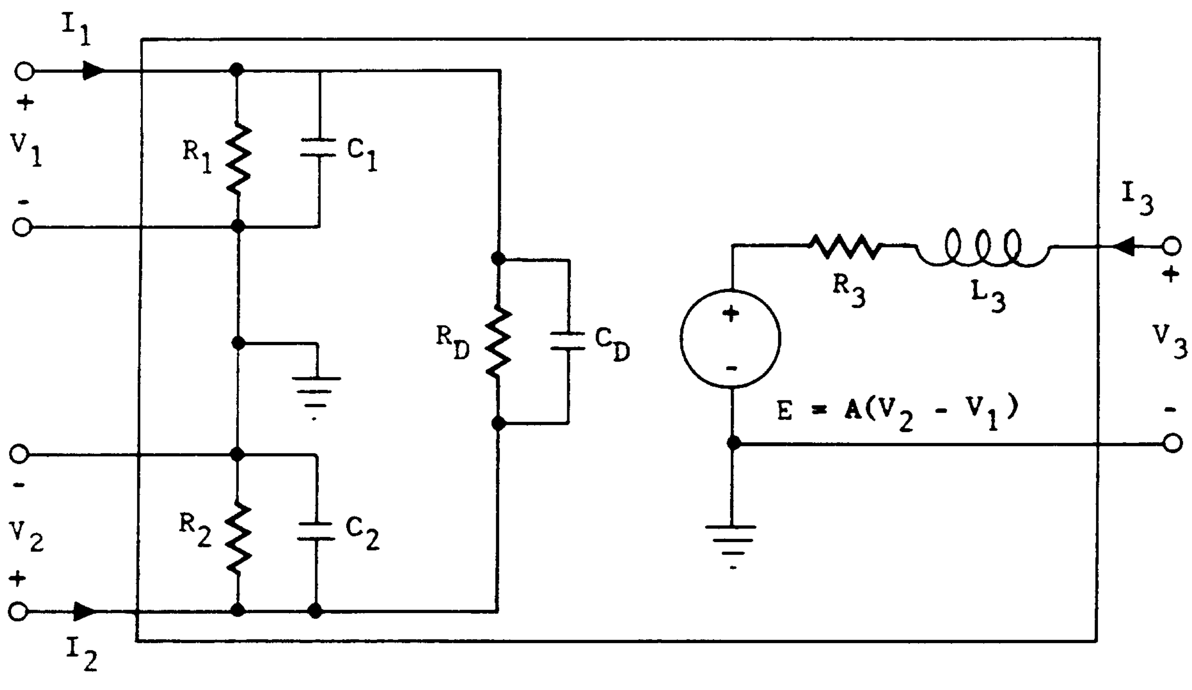
L_3 = Output inductance (H)

A_0 = dc open loop gain

$\omega_1, \omega_2, \omega_3$ = First three pole frequencies of the open loop transfer function (radians/sec)

f = frequency (Hz)

$\omega = 2\pi f$



Computed Parameters:

$$Y_1 = 1/R_1 + j\omega C_1$$

$$Y_2 = 1/R_2 + j\omega C_2$$

$$Y_3 = 1/(R_3 + j\omega L_3)$$

$$Y_D = 1/R_D + j\omega C_D$$

$$A = A_0/((1 + j\omega/\omega_1)(1 + j\omega/\omega_2)(1 + j\omega/\omega_3))$$

$$Y_{11} = Y_1 + Y_D$$

$$Y_{12} = -Y_D$$

$$Y_{13} = 0$$

$$Y_{21} = -Y_D$$

$$Y_{22} = Y_2 + Y_D$$

$$Y_{23} = 0$$

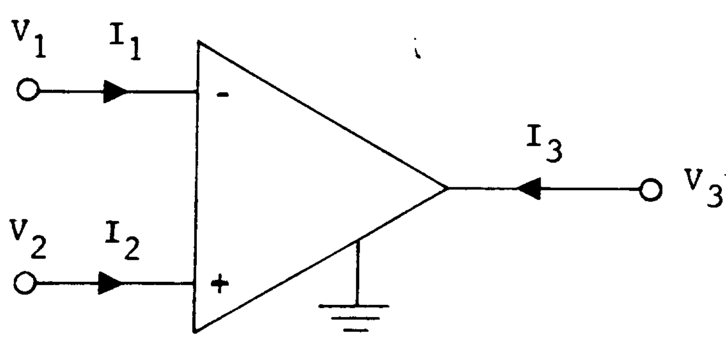
$$Y_{31} = AY_3$$

$$Y_{32} = -AY_3$$

$$Y_{33} = Y_3$$

Note that

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{32} & Y_{33} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix}$$



APPENDIX C

THE CONTROL ROUTINE USING A TRANSDUCER DESIGN EXAMPLE

This appendix presents a discussion of the operations that are written for a particular transducer design control routine. In this case, the specific problem dictates part of the routine; however, certain operations must be included in all control routines.

The first step in writing a control routine is to define the amount of storage to be used in the master storage area or blank common. The common block, DTA TOT, contains the variable, MX DATA, which is to be set by the user to the maximum number of storage cells to be used in blank common (i.e., the dimension size of the blank common array, DATA).

Secondly, the user must supply the port table description. The port table describes to the program the actual interconnection topology, series or parallel connection, and sign conventions. This operation is accomplished through subroutine LD PORT, which is called once for each accessible port of the network (Note: It is possible to define several networks at this time for use later in the program).

Following the description of the port table, each basic network that is referred to in the table must be described through a network description routine. A library of network description routines is available to include various types of networks, and may be easily expanded to handle any special types desired by the user. The purpose of these routines is to supply the data required to calculate the impedance matrix for the network (e.g., length, area, velocity of sound, etc.).

The control routine's major function is to perform the necessary calculations (or, as in most cases, the necessary calls to subroutines that perform the calculations) for the solution of the user's specific problem. Since the specific problems vary widely, a general structure for this portion cannot be provided. This approach offers the user maximum generality and flexibility for the solution of his problems.

The user must control through the routine the printed output of the problem. Several print flags can be turned on by the routine to provide some printed output; however, the user will have to supply some code to output the desired information.

The control routine's basic functions are illustrated by a routine written to investigate the changes in transducer performance caused by varying the transducer's tail length and ceramic area. Figure C.1 shows a diagram of the transducer. Figure C.2 shows the listing and associated printed output for the control routine. The problem in this case is to minimize $|Z_{ec}|$, the voltage-velocity control impedance of the radiating face (or, equivalently, $\gamma_{ec} = Z_{ec} + Z_{self}$, where Z_{self} = constant), as a function of both the number of ceramic pieces and the length of each ceramic piece. Lines 8-22 of figure C.2 are the common blocks needed for this run. Line 17 is a common block used only for this type of design procedure and is used primarily for transfer of information to RLIMMG, a subroutine that determines the real and imaginary parts as well as the magnitude of a complex function evaluated at a particular point. In this case, the function to be minimized is programmed into the subroutine.

Lines 27-33 contain pertinent data such as the names of networks to be involved in total length calculations, ceramic areas, and tail lengths.

Lines 46-59 define to the routine the interconnection table and sign conventions utilized by the user. Each of the basic networks that appears in the interconnection table is then described through particular network type calculations in lines 61-81.

Three major loops begin on lines 108 (tail lengths), 114 (ceramic areas), and 126 (number of ceramic pieces). The computations that are a function of these variables must be defined within these loops. The problem is to determine the number of pieces required to minimize $|\gamma_{ec}|$ and, using that number of ceramic pieces, to refine the estimate of the minimum by varying the ceramic piece length. The refined estimate is computed by both a pole-zero technique and a parabolic fit.

The subroutine RLIMMG is presented on pages 8, 9 and 10 of the computer print-out. Computer routine loading information appears on pages 11 through 22, while pages 23 through 30 are given to computer run output.

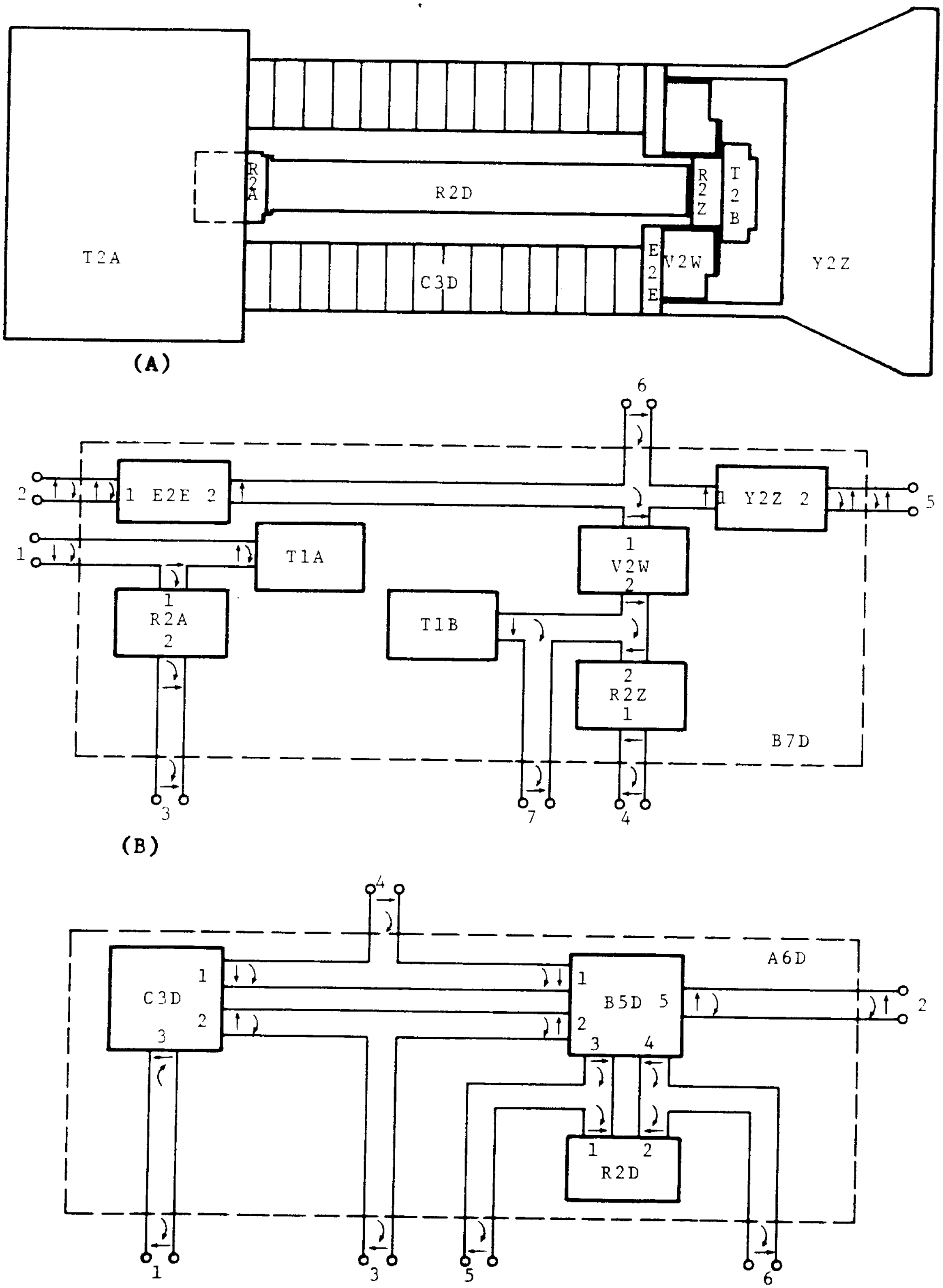


Figure C.1. Transducer Diagram and Interconnection Schematics. The figure includes (A) the transducer diagram, (B) the interconnection schematic for B7D, and (C) the interconnection schematic for A6D.

Figure C.2.

Listing and Output for Sample Control Routine for Transducer Design. This routine investigates the effects on the performance of a transducer element of varying the tail length and ceramic area.

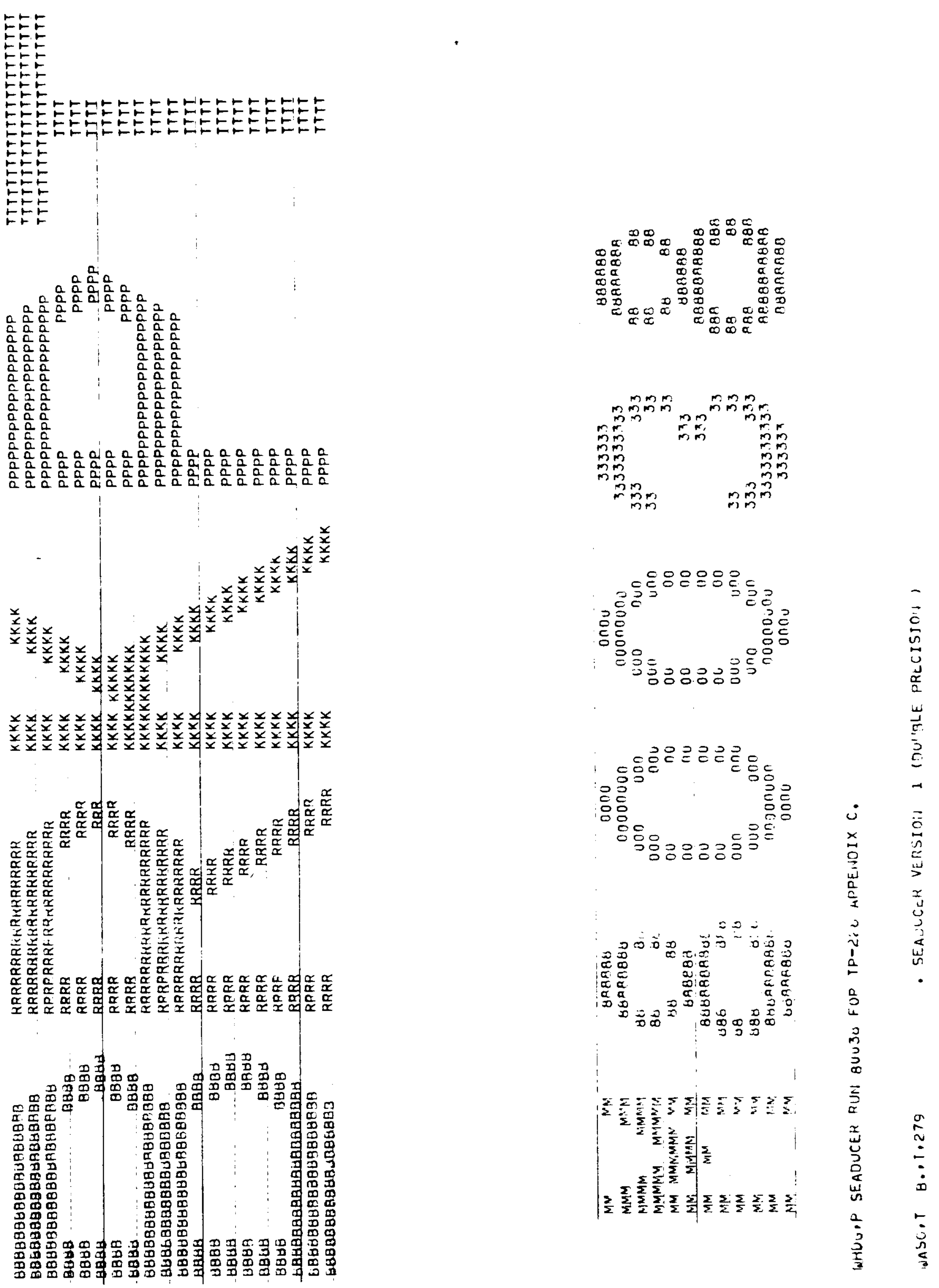


Figure C.2. (Continued).

```
SEADUCER RUN 6003B FOR TF-228 APPENDIX C                                  DATE 101972        PAGE      1

@COPIN B.,TPF$.
FURPUR 023A-10/19-19:40
 112 SYM  112 REL


@FREE   B.
```

Figure C.2. (Continued).

```
SEADUCER RUN 80036 FOR TR-228 APPENDIX C                                         DATE 101972        PAGE     2

@FOR,IS     CONTRL,CONTRL
FOR 0010-10/19/72-19:44:16 (,0)

  MAIN PROGRAM

  STORAGE USED: CODE(1) 001206; DATA(0) 000605; BLANK COMMON(2) 005050

   COMMON BLOCKS:

   0003    CATALG 001275
   0004    BASICB 000006
   0005    DTATOT 000001
   0006    TOTL   000002
   0007    TOTMAS 000002
   0010    PRTOFF 000001
   0011    CFMNPR 000001
   0012    CDESGN 000005
   0013    GMECIC 000020
   0014    CRMRCT 000006
   0015    CSRMTR 000001
   0016    FLGSRH 000004
   0017    CMNFMN 000003

  EXTERNAL REFERENCES (BLOCK, NAME)

   0020    DSQRT
   0021    SETCLK
   0022    PAGE
   0023    STRLIN
   0024    LDPORT
   0025    LDDT1
   0026    LDDT4
   0027    LDDT7
   0030    ALOCAT
   0031    LOCNAM
   0032    SKPLIN
   0033    LDIMTR
   0034    HEAD24
   0035    LDFREQ
   0036    BLDKKL
   0037    RDCPRT
   0040    LDDT11
   0041    FNDTL
   0042    LOCMTR
   0043    ZTOA
   0044    PRTMTR
   0045    LDAM2S
   0046    CMPGAM
   0047    EMFN
   0050    FNDTMS
   0051    SRMIDB
   0052    TIME
   0053    FNDNAM
   0054    PRPTBL
   0055    PRCTLG
   0056    NINTR$
```

Figure C.2. (Continued).

```
     0057    NPRT$
     0060    NIO2$
     0061    NWDC$
     0062    NSTOP$

  STORAGE ASSIGNMENT   (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0001     000722 100L      0001     000724 101L      0000     000424 149F      0001     001057 160L      0000     000443 165F
     0001     000453 251G      0001     000500 260G      0001     000542 274G      0000     000113 5F        0001     000660 98L
     0001     000715 99L       0000 R 000021 C3DAR     0002 D 000000 DATA      0004 D 000000 DF        0000 D 000000 DFRAND
     0013 D 000002 DGECI     0000 D 000004 DGECMG    0000 D 000002 DGECMN    0013 D 000000 DGECR     0013 D 000006 DGICI
     0013 D 000004 DGICR     0000 D 000006 DLC3D     0000 D 000010 DLMIN     0000 D 000012 DNONE     0004 D 000002 DOMEGA
     0004 D 000004 DPI       0014 D 000002 DQM       0014 D 000004 DREACT    0014 D 000000 DRM       0020 D 000000 DSQRT
     0006 D 000000 DTL       0007 D 000000 DTMASS    0013 D 000012 DZECI     0013 D 000010 DZECR     0013 D 000016 DZICI
     0013 D 000014 DZICR     0000 R 000056 FACTOR    0000 I 000077 IAA2D     0000 I 000111 IAY2Z4    0003     001274 ICLGSB
     0000 I 000062 ID2S      0016     000001 IECIC     0016 I 000003 IFLGLC    0016     000002 IFLGSP    0011 I 000000 IFMNPR
     0000 I 000057 IFORM     0000 I 000061 IF2S      0016     000000 IMXMN     0003     000310 IPC       0000 I 000060 IPUNCH
     0000 I 000063 IS2S      0003     000620 ITYPE     0000 I 000076 IZA2D     0000 I 000112 IZY2Z4    0000 I 000051 L
     0000 I 000026 LNAMES    0003 I 001130 LOC       0042 I 000000 LOCMTR    0031 I 000000 LOCNAM    0000 I 000032 LR2D1
     0000 I 000064 LTOP      0000 I 000110 LYZ       0000 I 000052 M         0017 I 000001 MAXSKP    0000 I 000070 MINCNT
     0017     000000 MINSKP    0000 I 000066 MTOP      0015 I 000000 MTRGVN    0003     000144 MTRSIZ    0005 I 000000 MXDATA
     0000 I 000073 N         0003     000000 NAME      0000 I 000044 NC        0003     000764 NDTSTR    0010 I 000000 NOPRT
     0003     000454 NPCTOT    0012 I 000003 NPGEMN    0000 I 000072 NPH1      0000 I 000071 NPLO      0000 I 000037 NT
     0000 I 000053 N1HUG     0017 I 000002 N1POLO    0012 R 000002 RAC3D     0012 R 000004 RAR2D1    0000 R 000067 RAY2Z3
     0000 R 000107 RGECMN    0000 R 000103 RGICMG    0000 R 000074 RLC3D     0000 R 000100 RLGEMN    0012 R 000000 RLR2A1
     0000 R 000075 RLR2D1    0012 R 000001 RLR2Z1    0000 R 000065 RLT2A1    0000 R 000055 RLY2Z4    0000 R 000054 RMY2Z4
     0000 R 000105 RPGEMN    0000 R 000104 RREACT    0000 R 000102 RTL       0000 R 000106 RTLC3D    0000 R 000101 RTMASS
     0000 R 000014 T2A1L


00101      1*         DOUBLE PRECISION   D F, D OMEGA, D PI                                   CONTRL
00103      2*         DOUBLE PRECISION   DATA                                                 CONTRL
00104      3*         DOUBLE PRECISION DT L, DT MASS                                          CONTRL
00105      4*         DOUBLE PRECISION  DGECR,DGECI,DGICR,DGICI, DZECR,DZECI,DZICR,DZICICONTRL
00106      5*         DOUBLE PRECISION    DRM, DQM, DREACT                                    CONTRL
00107      6*         DOUBLE PRECISION DFBAND, DGECMN, DGECMG, DLC3D, DLMIN, DNONE            CONTRL
00110      7*         DOUBLE PRECISION DSQRT                                                  CONTRL
00111      8*         COMMON / CATALG / NAME(100), MTR SIZ(100), I PC(100),
00111      9*        1     N PC TOT(100), I TYPE(100), N DT STR(100), LOC(100), I CLG SB
00112     10*         COMMON / BASIC 8 / D F, D OMEGA, D PI
00113     11*         COMMON / DTA TOT / MX DATA
00114     12*         COMMON /           / DATA(1300)
00115     13*         COMMON / TOT L / DT L
00116     14*         COMMON / TOT MAS / DT MASS
00117     15*         COMMON / PNT OFF / NO PRT
00120     16*         COMMON / C FMN PR / I FMN PR
00121     17*         COMMON / COESGN / RL R2A1, RL R2Z1, RA C3D, NP GE MN, RA R2D1
00122     18*         COMMON/ GM EC IC /DGECR,DGECI,DGICR,DGICI, DZECR,DZECI,DZICR,DZICI
00123     19*         COMMON / C RM RCT / DRM, DQM, DREACT
00124     20*         COMMON / C SRMTR / MTR GVN
00125     21*         COMMON / FLG SRH / I MX MN, I EC IC, I FLG SP, I FLG LC
00126     22*         COMMON / CMN FMN / MIN SKP, MAX SKP, N1 POL 0
00127     23*         DIMENSION T2A1 L(5), C3D AR(5)
00130     24*         DIMENSION L NAMES(4)
```

Figure C.2. (Continued).

```
00131    25*        DIMENSION L R2D1(5)
00132    26*        DIMENSION NT(5), NC(5)
00133    27*        DATA (NT(L),L=1,5 ) /'T1','T2','T3','T4','T5'/
00135    28*        DATA (NC(L),L=1,5 ) /'C1','C2','C3','C4','C5'/
00137    29*        DATA (L NAMES(L), L=1,4 ) / 'TA','CD','EE','YZ' /
00141    30*        DATA (L R2D1 (L), L=1,3 ) / 'VW','EE','CD'          /
00143    31*        DATA( C3D AR(M), M=1,5 ) / .0049, .0065, .00752, .0081, .012898 /
00145    32*        DATA( T2A1 L(L), L= 1, 5 ) /
00145    33*       /  .0381247, .0762493, .114374, .152499, .190623 /
00147    34*        DATA N1 HDG / 1 /
00151    35*        MX DATA = 1300
00152    36*
00152    37*        CALL SETCLK
00153    38*        CALL PAGE
00154    39*        CALL STR LIN
00155    40*        PRINT 5
00157    41*      5 FORMAT(' SEADUCER RUN 80038  APR 23,1970$ LIKE MOD 7 RUN 70335'/
00157    42*       /       ' DESIGN RUN $'/
00157    43*       /        ' LINES OF CONSTANT TAIL LENGTH$' /
00157    44*       /        ' CHARGE TO 16054501 BASELINE    '    )
00160    45*
00160    46*        CALL LD PORT ( 'S', '1B7D, -+1T1A, -+1R2A,$' )
00161    47*        CALL LD PORT ( 'S', '2B7D,    1E2E,$' )
00162    48*        CALL LD PORT ( 'S', '3B7D,    2R2A,$' )
00163    49*        CALL LD PORT ( 'S', '4B7D,    1R2Z,$' )
00164    50*        CALL LD PORT ( 'S', '5B7D,    2Y2Z,$' )
00165    51*        CALL LD PORT ( 'S', '6B7D, -+2E2E,    1V2W,  1Y2Z,$' )
00166    52*        CALL LD PORT ( 'S', '7B7D, -+1T1B,    2R2Z,  2V2W,$' )
00167    53*
00167    54*        CALL LD PORT ( 'S', '1A6D,    3C3D,$' )
00170    55*        CALL LD PORT ( 'S', '2A6D,    5B5D,$' )
00171    56*        CALL LD PORT ( 'S', '3A6D, -+2C3D,    2B5D,$' )
00172    57*        CALL LD PORT ( 'S', '4A6D, -+1B5D,    1C3D,$' )
00173    58*        CALL LD PORT ( 'S', '5A6D, -+3B5D,    1R2D,$' )
00174    59*        CALL LD PORT ( 'S', '6A6D, -+4B5D,    2R2D,$' )
00175    60*
00175    61*        CALL LD DT1('E2E1$',4416.90,1.48261E-2,0.,0.,.0090698,4820.,0.,0.)
00176    62*        RL R2A1 = .0072484
00177    63*        CALL LD DT1('R2A1$',7702.80,7.90233E-4,0.,0.,.0072484,4970.,0.,0.)
00200    64*        RL R2Z1 = .0006379
00201    65*        CALL LD DT1('R2Z1$',7702.80,7.90233E-4,0.,0.,.0006379,4970.,0.,0.)
00202    66*        CALL LD DT1('12B1$',7730.00,2.28639E-3,0.,0.,.0033570,4970.,0.,0.)
00203    67*        CALL LD DT1('12B2$',7724.87,1.68402E-3,0.,0.,.0033140,4970.,0.,0.)
00204    68*        CALL LD DT1('12B3$',7719.24,1.30699E-3,0.,0.,.0102145,4970.,0.,0.)
00205    69*        CALL LD DT1('12B4$',7702.80,7.90233E-4,0.,0.,.0066790,4970.,0.,0.)
00206    70*        CALL LD DT1('V2W1$',4416.90,1.12776E-2,0.,0.,.0113701,4820.,0.,0.)
00207    71*        CALL LD DT1('V2W2$',4416.90,1.12776E-2,0.,0.,.0113701,4820.,0.,0.)
00210    72*        CALL LD DT1('V2W3$',7768.48,2.54984E-3,0.,0.,.0022244,5116.,0.,0.)
00211    73*        CALL LD DT1('Y2Z1$',2702.81,3.48119E-3,0.,0.,.0113701,5200.,0.,0.)
00212    74*        CALL LD DT1('Y2Z2$',2702.81,3.48119E-3,0.,0.,.0113701,5200.,0.,0.)
00213    75*        CALL LD DT4('Y2Z3$',1.)
00214    76*        CALL PAGE
00215    77*        RM Y2Z4 = 2.755
00216    78*        RL Y2Z4 = .04516
00217    79*        FACTOR = 1.
00220    80*        I FORM = 0
00221    81*        CALL LD DT 7( 'Y2Z4$', FACTOR, I FORM)
```

Figure C.2. (Continued).

```
00222
00222        IPUNCH = 1
00223        IPUNCH = 0
00224        MAX SKP = 1
00225        N1 POL 0 = 1
00226
00226        CALL ALOCAT('FS', 2, 8)
00227        IF2S = LOC NAM('FS')
00230        CALL ALOCAT('DS', 2, 8)
00231        ID2S = LOC NAM('DS')
00232        CALL ALOCAT( 'SS', 2, 8)
00233        IS2S = LOC NAM('SS')
00234        CALL SKP LIN(1)
00235        CALL LD I MTR(IF2S, 2)
00236        CALL HEAD 24(' F2S UNIT MATRIX          ')
00237        CALL LD I MTR(ID2S, 2)
00240        CALL HEAD 24(' D2S UNIT MATRIX          ')
00241        CALL LD I MTR(IS2S, 2)
00242        CALL HEAD 24(' S2S UNIT MATRIX          ')
00243
00243        CALL PAGE
00244        DF = 3500.D0
00245        CALL LD FREQ( DF )
00246
00246        L TOP = 1
00247        L TOP = 5
00250        DO 300 L = 1, L TOP
00253        RL T2A1 = T2A1 L(L)
00254        CALL LD DT1('T2A1$',7832.48,2.17225E-2,0.,0., RL T2A1,5116.,0.,0.)
00255
00255        M TOP = 1
00256        M TOP = 5
00257        DO 200 M = 1, M TOP
00262        RA C3D = C3D AR(M)
00263        RAY2Z3 = RAC3D * 0.5
00264        CALL LD DT1('Y2Z3$',2702.81,RAY2Z3 ,0.,0.,.0353544,5200.,0.,0.)
00265        CALL BLD KKL('B7D$')
00266        CALL RDC PRT( 'B 7D$', 'R5D$' )
00267
00267        DGECMN = 1.E30
00270        MIN CNT = 0
00271        NP LO = 2
00272        NP HI = 26
00273
00273        DO 100 N = NP LO, NP HI, 2
00276        RL C3D = .0136253
00277        CALL LD DT 11('C3D$',N,7588.21, RA C3D ,0.0,0.0, RL C3D,
00277       E .1411666D4, 0.D0, .2419850-2,
00277       G .2452070D-1, 0.D0, -.187427D-3,
00277       S .940495D-11, 0.D0, .167029D-2 )
00300        CALL FND T L ( L R2D1, 3 )
00301        RL R2D1 = DT L - RL R2A1 - RL R271
00302        RA R2D1 = 5.71140E-4
00303        CALL LD DT1('R2D1$',7702.60, RA R2D1 , 0.,0., RL R2D1,4970.,0.,0.)
00304        IF ( NO PRT .EQ. 0 ) CALL PAGE
00306        NO PRT = 0
00307        NO PRT = 1
```

Figure C.2. (Continued).

```
00310
00310          CALL RLD KKL('A6D$')
00311          CALL RDC PRT( 'A6D$', 'A2D$' )
00312
00312          IZA2D = LOC MTR('AD', 2)
00313          IAA2D = IZA2D+8
00314          CALL Z TO A(IZA2D, IAA2D)
00315          IF ( NC PRT .NE. 0 ) GO TO 98
00317          CALL HEAD 24(' A A2D                       ')
00320          CALL PPT MTR(IAA2D, 2)
00321       98 CONTINUE
00322
00322          CALL LD A A2S
00323          CALL CMP GAM(IAA2D)
00324          DGECMG = DSQRT(DGECR**2+DGECI**2)                          CONTRL*
00325          IF ( DGECMG .GE. DGECMN ) GO TO 99
00327          DGECMN = DGECMG
00330          RLGE MN = RL C3D
00331          NPGEMN = N
00332          MIN CNT = MIN CNT + 1
00333          GO TO 100
00334       99 CONTINUE
00335          IF ( MIN CNT .GE. 2 ) GO TO 101
00337      100 CONTINUE
00341      101 CONTINUE
00342
00342          I FMN PR = 1
00343          I FMN PR = 0
00344          DL C3D = RL GE MN
00345          CALL FMFN( DL C3D, DNONE, DNONE, DL MIN, DGECMN )
00346
00346          CALL FND T MS
00347          RT MASS = DT MASS + RM Y224
00350          CALL FND T L ( L NAMES, 4 )
00351          RT L = DT L + RL Y224
00352          IF ( NO PRT .EQ. 0 ) CALL PAGE
00354          DRM = 1.D-30
00355          DQM = 1.D30
00356          DF BAND = DF
00357          MTR GVN = 1
00360          CALL SP MIND(DFBAND,  'MAX', 'IC', 'P', DRM, DQM )
00361          I FLG LC = 0
00362          RGICMG = DSQRT(DGICR**2+DGICI**2)                          CONTRL*
00363          RREACT = DREACT
00364          RPGEMN = NPGEMN
00365          RTLC3D = DL MIN * RPGEMN
00366          RGECMN = DGECMN
00367          IF ( N1 HDG .EQ. 0 ) GO TO 160
00371          N1 HDG = 0
00372          CALL SKP LIN(1)
00373          PRINT 149
00375          IF(IPUNCH.NE.0) PUNCH 5
00400          IF(IPUNCH.NE.0) PUNCH 149
00403      149 FORMAT(        '         L T2A1   A C3D   T L C3D   NP T MASS '
00403         1                 'T LENGTH  REACTOR  GAMMA IC GAM EC MIN')
00404      160 CONTINUE
00405          PRINT 165,
```

Figure C.2. (Continued).

```
00405   196*          1          NT(L), NC(M), PL T2A1, RA C3D, RTL C3D, NPGEMN,
00405   197*          2          RTMASS, RTL, RREACT, RGICMG, RGECMN
00422   198*           IF ( IPUNCH .NE. 0 ) PUNCH 165,
00422   199*          1          NT(L), NC(M), PL T2A1, RA C3D, RTL C3D, NPGEMN,
00422   200*          2          RTMASS, RTL, RREACT, RGICMG, RGECMN
00440   201*       165 FORMAT( 1X, A2,A2,2X, 3F8.6, I3,     F8.4, F8.5, 3E10.4 )
00441   202*
00441   203*       200 CONTINUE
00441   204*     C 200 EXIT C3D AREA LOOP
00443   205*
00443   206*           CALL SKP LIN(1)
00444   207*       300 CONTINUE
00444   208*     C 300 EXIT T2L LENGTH LOOP
00446   209*
00446   210*           CALL TIME
00447   211*           CALL FND NAM('YZ',LYZ)
00450   212*           IAY2Z4 = LOC(LYZ+4)
00451   213*           IZY2Z4 = IAY2Z4 + 8
00452   214*           CALL SKPLIN(2)
00453   215*           CALL HEAD 24('    A Y2Z4
00454   216*           CALL PRT MTR(IA Y2Z4,2)
00455   217*           CALL SKPLIN(2)
00456   218*           CALL HEAD 24('    Z Y2Z4
00457   219*           CALL PRT MTR(IZ Y2Z4,2)
00460   220*
00460   221*           CALL PAGE
00461   222*           CALL PR PTBL
00462   223*           CALL PAGE
00463   224*           CALL PR CTLG
00464   225*           CALL PAGE
00465   226*           CALL TIME
00466   227*           STOP
00467   228*           END

      END OF COMPILATION:        NO  DIAGNOSTICS.
```

Figure C.2. (Continued).

```
SEAUUCER RUN 80038 FOR TP-228 APPENDIX C                                                     DATE 101972        PAGE     8

WFOR,IS      RLIMMG,RLIMMG
FOR 0010-10/19/72-19:44:28 (,0)

   SUBROUTINE RLIMMG     ENTRY POINT 000167

  STORAGE USED: CODE(1) 000205; DATA(0) 000102; BLANK COMMON(2) 000310

   COMMON BLOCKS:

   0003    CEMNPR 000001
   0004    PRTOFF 000001
   0005    IOTL   000002
   0006    GMECIC 000020
   0007    LDESGN 000005

  EXTERNAL REFERENCES (BLOCK, NAME)

   0010    DSQRT
   0011    PAGE
   0012    LPDT11
   0013    FNDIL
   0014    LPDT1
   0015    BLDKKL
   0016    RDCPRT
   0017    LOCMTR
   0020    ZTOA
   0021    HEAD24
   0022    PRTMTR
   0023    LDAM2S
   0024    CMPGAM
   0025    PRMARI
   0026    NERR3$

  STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

   0001   000121 9L        0002 D 000000 DATA      0006 D 000002 DGECI     0006 D 000000 DGECR     0006 D 000006 DGICI
   0006 D 000004 DGICR     0010 D 000000 DSQRT     0005 D 000000 DTL       0006 D 000012 DZECI     0006 D 000010 DZECR
   0006 D 000016 DZICI     0006 D 000014 DZICR     0000 I 000013 IAA2D     0003 I 000000 IFMNPR    0000   000071 INJP$
   0000 I 000012 IZA2D     0000 I 000005 L         0017 I 000000 LOCATR    0000 I 000000 LR2D1     0000 I 000007 N
   0000 I 000006 NOPRSV    0004 I 000000 NOPRT     0007 I 000003 NPGEMN    0007 R 000002 RAC3D     0007 R 000004 RAR2D1
   0000 R 000010 RLC3D     0007 R 000000 RLR2A1    0000 R 000011 RLR2D1    0007 R 000001 RLR2Z1


00101       1*        SUBROUTINE RL IM MG(DX, DRL, DIM, DMG)
00103       2*        DOUBLE PRECISION    DX, DRL, DIM, DMG                            RLIMMG
00104       3*        DOUBLE PRECISION    DATA                                         RLIMMG
00105       4*        DOUBLE PRECISION DSQRT                                           RLIMMG
00106       5*        DOUBLE PRECISION DT                                              RLIMMG
00107       6*        DOUBLE PRECISION DGECR,DGECI,DGICR,DGICI,DZECR,DZECI,DZICR,DZICI RLIMMG
00110       7*        COMMON /          / DATA( 100)
00111       8*        COMMON / C FMN PR / I FMN PR
```

Figure C.2. (Continued).

```
00112      9*          COMMON / PRT OFF / NO PRT
00113     10*
00113     11*          COMMON / TOT L / DT L
00114     12*          COMMON/ GM EC IC /DGECR,DGECI,DGICR,DGICI, DZECR,DZECI,DZICR,DZICI
00115     13*          COMMON / DESGN / RL R2A1, RL R2Z1, RA C3D, NP GE MN, RA R2D1
00116     14*          DIMENSION L R2D1(5)
00117     15*          DATA (L R2D1 (L), L=1,3 ) / 'VW','EE','CD'          /
00121     16*
00121     17*    C * * * * * * * PROGRAMMED BY L. E. MCCLEARY  NUC CODE 601 * * * * * * *
00121     18*
00121     19*    C * * * * * SUBROUTINE USED FOR EVALUATING A MOD 8 FUNCTION AT DX
00121     20*    C * * * * * TO RETURN THE REAL, IMAG, AND MAGNITUDE OF A COMPLEX NUMBER
00121     21*
00121     22*    C * * * * * CHANGE THESE STATEMENTS TO LOAD THE INDEP. VARIABLE (DX)
00121     23*          NO PR SV = NO PRT
00122     24*          NO PRT = 1 - I FMN PR
00123     25*
00123     26*          IF ( NO PRT .EQ. 0 ) CALL PAGE
00125     27*          N = NP GE MN
00126     28*          RL C3D = DX
00127     29*          CALL LD DT 11('C3D$',N,7588.21, RA C3D ,0.0,0.0, RL C3D,
00127     30*         E .141166D04, 0.D0, .241985D-2,
00127     31*         G .245207D-1, 0.D0, -.187427D-3,
00127     32*         S .940495D-11, 0.D0, .167029D-2 )
00130     33*          CALL FND T L ( L R2D1, 3 )
00131     34*          RL R2D1 = DT L - RL R2A1 - RL R2Z1
00132     35*          CALL LD DT 1('R2D1$',7702.80,RA R2D1,0.,0.,RL R2D1,4970.,0.,0.)
00133     36*
00133     37*          NO PRT = NO PR SV
00134     38*
00134     39*    C * * * * * CHANGE THESE STATEMENTS TO COMPUTE THE FUNCTION (DRL, DIM)
00134     40*
00134     41*    C             THIS EXAMPLE IS FOR DESIGN RUNS 80038, 80047, 80050,
00134     42*          CALL RLD K/L('A6D$')
00135     43*          CALL RDC PRT( 'A6D$', 'A2D$' )
00136     44*          IZA2D = LOC MTR('AD', 2)
00137     45*          IAA2D = IZA2D+8
00140     46*          CALL Z TO N(IZA2D, IAA2D)
00141     47*          IF ( NO PRT .NE. 0 ) GO TO 9
00143     48*          CALL HEAD 24(' A A2D                  ')
00144     49*          CALL PRT MTR(IAA2D, 2)
00145     50*        9 CONTINUE
00146     51*          CALL LD A 2S
00147     52*          CALL CMP GAM(IAA2D)
00150     53*          DRL = DGECR
00151     54*          DIM = DGECI
00152     55*
00152     56*    C * * * * * COMPUTE DMG
00152     57*          DMG = DSQRT(DRL**2+DIM**2)                                              RLIMMG*
00153     58*
00153     59*    C * * * * * FUNCTION PRINTOUTS
00153     60*          IF ( I FMN PR .EQ. 0 ) RETURN
00155     61*
00155     62*          CALL HEAD 24(' GAMMA EC                ')
00156     63*          CALL PR MAT(1, 'DEG', DRL, DIM)
00157     64*
00157     65*          RETURN
```

Figure C.2. (Continued).

LDDT4	RELOCATABLE	28 MAR 72	23:17:32	44	2	13				2390
LDDT5	FOR SYMB	28 MAR 72	23:17:33	45		17	5	0	1	2405
LDDT5	RELOCATABLE	28 MAR 72	23:17:34	46	2	11				2422
LDDT7	FOR SYMB	28 MAR 72	23:17:36	47		51	5	0	1	2435
LDDT7	RELOCATABLE	28 MAR 72	23:17:38	48	2	30				2486
TYPE7	FOR SYMB	28 MAR 72	23:17:39	49		28	5	0	1	2518
TYPE7	RELOCATABLE	28 MAR 72	23:17:42	50	1	23				2546
LDDT8	FOR SYMB	28 MAR 72	23:17:42	51		22	5	0	1	2570
LDDT8	RELOCATABLE	28 MAR 72	23:17:44	52	3	20				2592
LDDT9	FOR SYMB	28 MAR 72	23:17:46	53		22	5	0	1	2615
LDDT9	RELOCATABLE	28 MAR 72	23:17:48	54	3	20				2637
LDDT11	FOR SYMB	28 MAR 72	23:17:49	55		26	5	0	1	2660
LDDT11	RELOCATABLE	28 MAR 72	23:17:51	56	3	19				2686
TYPE11	FOR SYMB	28 MAR 72	23:17:52	57		31	5	0	1	2708
TYPE11	RELOCATABLE	28 MAR 72	23:17:55	58	2	29				2739
T11SBR	FOR SYMB	28 MAR 72	23:17:55	59		11	5	0	1	2770
T11SBR	RELOCATABLE	28 MAR 72	23:17:57	60	2	11				2781
LDDT14	FOR SYMB	28 MAR 72	23:17:58	61		25	5	0	1	2794
LDDT14	RELOCATABLE	28 MAR 72	23:18:00	62	3	19				2819
TYPE14	FOR SYMB	28 MAR 72	23:18:00	63		3	5	0	1	2841
TYPE14	RELOCATABLE	28 MAR 72	23:18:01	64	1	2				2844
LDDT15	FOR SYMB	28 MAR 72	23:18:03	65		26	5	0	1	2847
LDDT15	RELOCATABLE	28 MAR 72	23:18:04	66	3	21				2873
TYPE15	FOR SYMB	28 MAR 72	23:18:05	67		3	5	0	1	2897
TYPE15	RELOCATABLE	28 MAR 72	23:18:06	68	1	2				2900
T1415S	FOR SYMB	28 MAR 72	23:18:07	69		9	5	0	1	2903
T1415S	RELOCATABLE	28 MAR 72	23:18:08	70	2	10				2912
TP1415	FOR SYMB	28 MAR 72	23:18:09	71		19	5	0	1	2924
TP1415	RELOCATABLE	28 MAR 72	23:18:11	72	2	20				2943
LDDT20	FOR SYMB	28 MAR 72	23:18:12	73		19	5	0	1	2965
LDDT20	RELOCATABLE	28 MAR 72	23:18:13	74	2	14				2984
TYPE20	FOR SYMB	28 MAR 72	23:18:14	75		13	5	0	1	3000
TYPE20	RELOCATABLE	28 MAR 72	23:18:15	76	2	10				3013
LDDT21	FOR SYMB	28 MAR 72	23:18:16	77		17	5	0	1	3025
LDDT21	RELOCATABLE	28 MAR 72	23:18:18	78	2	12				3042
TYPE21	FOR SYMB	28 MAR 72	23:18:19	79		5	5	0	1	3056
TYPE21	RELOCATABLE	28 MAR 72	23:18:19	80	1	3				3061
LDDT22	FOR SYMB	28 MAR 72	23:18:21	81		17	5	0	1	3065
LDDT22	RELOCATABLE	28 MAR 72	23:18:22	82	2	12				3082
TYPE22	FOR SYMB	28 MAR 72	23:18:22	83		5	5	0	1	3096
TYPE22	RELOCATABLE	28 MAR 72	23:18:24	84	1	4				3101
LDDT24	FOR SYMB	28 MAR 72	23:18:25	85		17	5	0	1	3106
LDDT24	RELOCATABLE	28 MAR 72	23:18:26	86	2	12				3123
TYPE24	FOR SYMB	28 MAR 72	23:18:27	87		5	5	0	1	3137
TYPE24	RELOCATABLE	28 MAR 72	23:18:28	88	1	4				3142
LDDT25	FOR SYMB	28 MAR 72	23:18:29	89		17	5	0	1	3147
LDDT25	RELOCATABLE	28 MAR 72	23:18:30	90	2	12				3164
TYPE25	FOR SYMB	28 MAR 72	23:18:31	91		5	5	0	1	3178
TYPE25	RELOCATABLE	28 MAR 72	23:18:32	92	1	4				3183
LDDT26	FOR SYMB	28 MAR 72	23:18:33	93		19	5	0	1	3188
LDDT26	RELOCATABLE	28 MAR 72	23:18:34	94	2	14				3207
TYPE26	FOR SYMB	28 MAR 72	23:18:35	95		14	5	0	1	3223
TYPE26	RELOCATABLE	28 MAR 72	23:18:37	96	2	13				3237
AIDOD	FOR SYMB	28 MAR 72	23:18:37	97		12	5	0	1	3252
AIDOD	RELOCATABLE	28 MAR 72	23:18:39	98	1	8				3264
LA2BY2	FOR SYMB	28 MAR 72	23:18:39	99		4	5	0	1	3273
LA2BY2	RELOCATABLE	28 MAR 72	23:18:40	100	1	2				3277

Figure C.2. (Continued).

LZ2BY2	FOR SYMB	28 MAR 72	23:18:40	101		4	5	0	1	3280
LZ2BY2	RELOCATABLE	28 MAR 72	23:18:42	102	1	2				3284
LZ3BY3	FOR SYMB	28 MAR 72	23:18:42	103		4	5	0	1	3287
LZ3BY3	RELOCATABLE	28 MAR 72	23:18:43	104	1	2				3291
LY2BY2	FOR SYMB	28 MAR 72	23:18:44	105		4	5	0	1	3294
LY2BY2	RELOCATABLE	28 MAR 72	23:18:45	106	1	2				3298
LY3BY3	FOR SYMB	28 MAR 72	23:18:46	107		4	5	0	1	3301
LY3BY3	RELOCATABLE	28 MAR 72	23:18:47	108	1	2				3305
LDDRIM	FOR SYMB	28 MAR 72	23:18:48	109		5	5	0	1	3308
LDDRIM	RELOCATABLE	28 MAR 72	23:18:49	110	1	4				3313
LDSB11	FOR SYMB	28 MAR 72	23:18:49	111		7	5	0	1	3318
LDSB11	RELOCATABLE	28 MAR 72	23:18:51	112	1	3				3325
LS1415	FOR SYMB	28 MAR 72	23:18:51	113		6	5	0	1	3329
LS1415	RELOCATABLE	28 MAR 72	23:18:52	114	1	3				3335
FNDTMS	FOR SYMB	28 MAR 72	23:18:53	115		9	5	0	1	3339
FNDTMS	RELOCATABLE	28 MAR 72	23:18:54	116	2	5				3348
FNDTL	FOR SYMB	28 MAR 72	23:18:55	117		13	5	0	1	3355
FNDTL	RELOCATABLE	28 MAR 72	23:18:56	118	2	9				3368
MTRMOV	FOR SYMB	28 MAR 72	23:18:57	119		4	5	0	1	3379
MTRMOV	RELOCATABLE	28 MAR 72	23:18:58	120	1	3				3383
MTRMUL	FOR SYMB	28 MAR 72	23:18:59	121		12	5	0	1	3387
MTRMUL	RELOCATABLE	28 MAR 72	23:19:00	122	1	11				3399
DLETRC	FOR SYMB	28 MAR 72	23:19:01	123		11	5	0	1	3411
DLETRC	RELOCATABLE	28 MAR 72	23:19:03	124	1	7				3422
LDIMTR	FOR SYMB	28 MAR 72	23:19:03	125		4	5	0	1	3430
LDIMTR	RELOCATABLE	28 MAR 72	23:19:04	126	1	4				3434
DECOMB	FOR SYMB	28 MAR 72	23:19:06	127		45	5	0	1	3439
DECOMB	RELOCATABLE	28 MAR 72	23:19:10	128	2	55				3484
ATOZ	FOR SYMB	28 MAR 72	23:19:10	129		10	5	0	1	3541
ATOZ	RELOCATABLE	28 MAR 72	23:19:12	130	2	9				3551
ZTOA	FOR SYMB	28 MAR 72	23:19:13	131		10	5	0	1	3562
ZTOA	RELOCATABLE	28 MAR 72	23:19:15	132	2	9				3572
ATOY	FOR SYMB	28 MAR 72	23:19:16	133		9	5	0	1	3583
ATOY	RELOCATABLE	28 MAR 72	23:19:17	134	2	11				3592
YTOA	FOR SYMB	28 MAR 72	23:19:18	135		9	5	0	1	3605
YTOA	RELOCATABLE	28 MAR 72	23:19:19	136	2	11				3614
DACMUL	FOR SYMB	28 MAR 72	23:19:20	137		3	5	0	1	3627
DACMUL	RELOCATABLE	28 MAR 72	23:19:21	138	1	2				3630
DCMMUL	FOR SYMB	28 MAR 72	23:19:22	139		3	5	0	1	3633
DCMMUL	RELOCATABLE	28 MAR 72	23:19:23	140	1	2				3636
DCMDIV	FOR SYMB	28 MAR 72	23:19:24	141		3	5	0	1	3639
DCMDIV	RELOCATABLE	28 MAR 72	23:19:25	142	1	3				3642
DCRCIP	FOR SYMB	28 MAR 72	23:19:25	143		3	5	0	1	3646
DCRCIP	RELOCATABLE	28 MAR 72	23:19:27	144	1	2				3649
DCSQRT	FOR SYMB	28 MAR 72	23:19:28	145		10	5	0	1	3652
DCSQRT	RELOCATABLE	28 MAR 72	23:19:29	146	1	9				3662
DCANG1	FOR SYMB	28 MAR 72	23:19:30	147		8	5	0	1	3672
DCANG1	RELOCATABLE	28 MAR 72	23:19:31	148	1	6				3680
DCACSH	FOR SYMB	28 MAR 72	23:19:32	149		5	5	0	1	3687
DCACSH	RELOCATABLE	28 MAR 72	23:19:33	150	1	4				3692
DSHCH	FOR SYMB	28 MAR 72	23:19:34	151		4	5	0	1	3697
DSHCH	RELOCATABLE	28 MAR 72	23:19:35	152	1	3				3701
DCSNCS	FOR SYMB	28 MAR 72	23:19:36	153		5	5	0	1	3705
DCSNCS	RELOCATABLE	28 MAR 72	23:19:37	154	1	3				3710
DCSHCH	FOR SYMB	28 MAR 72	23:19:37	155		5	5	0	1	3714
DCSHCH	RELOCATABLE	28 MAR 72	23:19:39	156	1	3				3719
PRTMTR	FOR SYMB	28 MAR 72	23:19:40	157		5	5	0	1	3723

Figure C.2. (Continued).

	PRTMTR	RELOCATABLE	28 MAR 72	23:19:41	158	1	5				3728
	PRTMBN	FOR SYMB	28 MAR 72	23:19:42	159		5	5	0	1	3734
	PRTMBN	RELOCATABLE	28 MAR 72	23:19:43	160	1	5				3739
	PRMARI	FOR SYMB	28 MAR 72	23:19:43	161		8	5	0	1	3745
	PRMARI	RELOCATABLE	28 MAR 72	23:19:45	162	2	6				3753
	HEAD24	FOR SYMB	28 MAR 72	23:19:45	163		6	5	0	1	3761
	HEAD24	RELOCATABLE	28 MAR 72	23:19:47	164	1	6				3767
	PAGE	FOR SYMB	28 MAR 72	23:19:48	165		1	5	0	1	3774
	PAGE	RELOCATABLE	28 MAR 72	23:19:49	166	1	2				3775
	STRLIN	FOR SYMB	28 MAR 72	23:19:49	167		2	5	0	1	3778
	STRLIN	RELOCATABLE	28 MAR 72	23:19:51	168	1	2				3780
	SKPLIN	FOR SYMB	28 MAR 72	23:19:51	169		2	5	0	1	3783
	SKPLIN	RELOCATABLE	28 MAR 72	23:19:52	170	1	2				3785
	PRPTBL	FOR SYMB	28 MAR 72	23:19:53	171		7	5	0	1	3788
	PRPTBL	RELOCATABLE	28 MAR 72	23:19:54	172	1	5				3795
	PRCTLG	FOR SYMB	28 MAR 72	23:19:55	173		6	5	0	1	3801
	PRCTLG	RELOCATABLE	28 MAR 72	23:19:55	174	2	5				3807
	UNPACK	FOR SYMB	28 MAR 72	23:19:57	175		26	5	0	1	3814
	UNPACK	RELOCATABLE	28 MAR 72	23:19:59	176	1	22				3840
	BLKDTA	FOR SYMB	28 MAR 72	23:20:00	177		15	5	0	1	3863
	BLKDTA	RELOCATABLE	28 MAR 72	23:20:00	178	4	3				3878
	TIME	FOR SYMB	28 MAR 72	23:20:01	179		5	5	0	1	3885
	TIME	RELOCATABLE	28 MAR 72	23:20:02	180	1	3				3890
	Z1TOZ2	FOR SYMB	28 MAR 72	23:20:03	181		8	5	0	1	3894
	Z1TOZ2	RELOCATABLE	28 MAR 72	23:20:04	182	1	6				3902
	DCPCT2	FOR SYMB	28 MAR 72	23:20:05	183		9	5	0	1	3909
	DCPCT2	RELOCATABLE	28 MAR 72	23:20:06	184	1	7				3918
	FNDKRC	FOR SYMB	28 MAR 72	23:20:07	185		26	5	0	1	3926
	FNDKRC	RELOCATABLE	28 MAR 72	23:20:09	186	2	20				3952
	SRCHBC	FOR SYMB	28 MAR 72	23:20:12	187		101	5	0	1	3974
	SRCHBC	RELOCATABLE	28 MAR 72	23:20:16	188	4	76				4075
	MINCHK	FOR SYMB	28 MAR 72	23:20:16	189		3	5	0	1	4155
	MINCHK	RELOCATABLE	28 MAR 72	23:20:18	190	1	2				4158
	MAXCHK	FOR SYMB	28 MAR 72	23:20:18	191		3	5	0	1	4161
	MAXCHK	RELOCATABLE	28 MAR 72	23:20:19	192	1	2				4164
	CMPZS	FOR SYMB	28 MAR 72	23:20:19	193		5	5	0	1	4167
	CMPZS	RELOCATABLE	28 MAR 72	23:20:21	194	2	3				4172
	PREPZV	FOR SYMB	28 MAR 72	23:20:22	195		16	5	0	1	4177
	PREPZV	RELOCATABLE	28 MAR 72	23:20:23	196	2	18				4193
	FNDFZV	FOR SYMB	28 MAR 72	23:20:24	197		7	5	0	1	4213
	FNDFZV	RELOCATABLE	28 MAR 72	23:20:25	198	2	5				4220
	LDZRVR	FOR SYMB	28 MAR 72	23:20:25	199		5	5	0	1	4227
	LDZRVR	RELOCATABLE	28 MAR 72	23:20:27	200	2	3				4232
	SRMIDB	FOR SYMB	28 MAR 72	23:20:29	201		57	5	0	1	4237
	SRMIDB	RELOCATABLE	28 MAR 72	23:20:32	202	4	50				4294
	LDAM2S	FOR SYMB	28 MAR 72	23:20:33	203		19	5	0	1	4348
	LDAM2S	RELOCATABLE	28 MAR 72	23:20:34	204	3	15				4367
	CMPGAM	FOR SYMB	28 MAR 72	23:20:36	205		16	5	0	1	4385
	CMPGAM	RELOCATABLE	28 MAR 72	23:20:37	206	2	14				4401
	FSRCH	FOR SYMB	28 MAR 72	23:20:41	207		142	5	0	1	4417
	FSRCH	RELOCATABLE	28 MAR 72	23:20:48	208	5	123				4559
*	RLIMMG	FOR SYMB	28 MAR 72	23:20:48	209		10	5	0	1	4687
*	RLIMMG	RELOCATABLE	28 MAR 72	23:20:49	210	2	6				4697
	EMEN	FOR SYMB	28 MAR 72	23:20:50	211		6	5	0	1	4705
	EMEN	RELOCATABLE	28 MAR 72	23:20:51	212	2	5				4711
	POLEQ	FOR SYMB	28 MAR 72	23:20:52	213		14	5	0	1	4718
	POLEQ	RELOCATABLE	28 MAR 72	23:20:54	214	1	13				4732

Figure C.2. (Continued).

PRBFIT	FOR SYMB	28 MAR 72	23:20:54	215'		9	5	0	1	4746
PRBFIT	RELOCATABLE	28 MAR 72	23:20:55	216	1	7				4755
FNDPRM	FOR SYMB	28 MAR 72	23:20:57	217		40	5	0	1	4763
FNDPRM	RELOCATABLE	28 MAR 72	23:21:00	218	4	29				4803
FNDFDP	FOR SYMB	28 MAR 72	23:21:00	219		8	5	0	1	4836
FNDFDP	RELOCATABLE	28 MAR 72	23:21:01	220	2	3				4844
LDBCOL	FOR SYMB	28 MAR 72	23:21:02	221		6	5	0	1	4849
LDBCOL	RELOCATABLE	28 MAR 72	23:21:03	222	2	4				4855
PRTPRM	FOR SYMB	28 MAR 72	23:21:04	223		14	5	0	1	4861
PRTPRM	RELOCATABLE	28 MAR 72	23:21:05	224	2	9				4875
CONTRL	FOR SYMB	19 OCT 72	19:44:24	225		56	5	0	1	4886
CONTRL	RELOCATABLE	19 OCT 72	19:44:28	226	6	58				4942
RLIMMG	FOR SYMB	19 OCT 72	19:44:28	227		17	5	0	1	5006
RLIMMG	RELOCATABLE	19 OCT 72	19:44:30	228	3	11				5023
NEXT AVAILABLE LOCATION-										5037

ASSEMBLER PROCEDURE TABLE EMPTY

COBOL PROCEDURE TABLE EMPTY

FORTRAN PROCEDURE TABLE EMPTY

ENTRY POINT TABLE

D NAME	LINK	D NAME	LINK	D NAME	LINK	D NAME	LINK	D NAME	LINK
AIDQQ	98	ALOCAT	18	ATOY	134	ATOZ	130	BLDKKL	8
BLDMTR	6	CASCDE	32	CHKSTR	20	CMPGAM	206	CMPZS	194
DACMUL	138	DCACSH	150	DCANG1	148	DCMDIV	142	DCMMUL	140
DCPCT2	184	DCRCIP	144	DCSHCH	156	DCSNCS	154	DCSORT	146
DECOMB	128	DLETRC	124	DSHCH	152	FMEN	212	FNDFDP	220
FNDFZV	198	FNDKRC	186	FNDLCJ	16	FNDMTR	28	FNDNAM	30
FNDNET	22	FNDPRM	218	FNDTL	118	FNDTMS	116	FORMAINS	226
FSRCH	208	HEAD24	164	LA2BY2	100	LDAM2S	204	LDRCOL	222
LDDRIM	110	LDDT1	36	LDDT11	56	LDDT14	62	LDDT15	66
LDDT2	40	LDDT20	74	LDDT21	78	LDDT22	82	LDDT24	86
LDDT25	90	LDDT26	94	LDDT4	44	LDDT5	46	LDDT7	48
LDDT8	52	LDDT9	54	LDFREQ	12	LDIMTR	126	LDPORT	4
LDSB11	112	LDZRVR	200	LOCMTR	24	LOCNAM	26	LS1415	114
LY2BY2	106	LY3BY3	108	LZ2BY2	102	LZ3BY3	104	MAXCHK	192
MINCHK	190	MTRMOV	120	MTRMUL	122	PAGE	166	POLFO	214
PRBFIT	216	PRCTLG	174	PREP7V	196	PRMARI	162	PRPTBL	172
PRIMBN	160	PRTMTR	158	PRTPRM	224	RDCPRT	10	RLIMMG	228
SKPLIN	170	SRCHBC	188	SRMIDB	202	STRLIN	168	TIME	180
TP1415	72	TYPCAL	34	TYPE1	38	TYPE11	58	TYPE14	64
TYPE15	68	TYPE2	42	TYPE20	76	TYPE21	80	TYPE22	84
TYPE24	88	TYPE25	92	TYPE26	96	TYPE7	50	T11SBR	60
T1415S	70	UNPACK	176	UPPTBL	14	YTOA	136	ZTOA	132
Z1TOZ2	182								

Figure C.2. (Continued).

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SEADUCER RUN 80038 FOR TP-22P APPENDIX C                                          DATE 101972      PAGE    16

WMAP,XIB     SYMRUN,ABSRUN
MAP 0022-10/19-19:44 -(,0)

    1.        IN CONTRL

    2.        IN BLKDTA



ADDRESS LIMITS     001000 040112      041000 064762
STARTING ADDRESS   036765

WORDS DECIMAL       15947 IBANK        10227 DBANK


             SEGMENT MAIN            001000 040112       041000 064762

NSWTCS/FOR                1   001000 001021
NRBLK$/FOR-NUC            1   001022 001047
NRWND$/FOR50-NUC          1   001050 001127      2   041000 041011
NWEF$/FOR55               1   001130 001322      2   041012 04103[illegible]
NFTCH$/FOR57              1   001323 001622      2   041032 041067
NCLOS$/FOR57              1   001623 001761      2   041070 041114
NWBLK$/FOR57-NUC          1   001762 002104
NBSBL$/FOR                1   002105 002142
NUPDA$/FOR                1   002143 002176
NBF00$/FOR                                       2   041115 043316
NBDCV$/FOR57              1   002177 002332      2   043317 043356
NFTV$/FOR                 1   002333 002355
NCNVT$/FOR57              1   002356 002610      2   043357 043446
NININ$/FOR55              1   002611 003034      2   043447 043470
NINPT$/FOR57              1   003035 003714      2   043471 043513
NFCHK$/FOR57              1   003715 004516      2   043514 043655
                                                 4   043656 043727
NIUER$/FOR57              1   004517 004635      2   043730 044032
NOUT$/FOR57-UNIV          1   004636 005605      2   044033 044063
NFMT$/FOR57               1   005606 006512      2   044064 044102
NTAB$/FOR                                        2   044103 044141
ERU$/57
DEXP$/FOR54               1   006513 006661      2   044142 044175
DLOG$/FOR54               1   006662 007002      2   044176 044302
DSINCOS$/FOR57            1   007003 007144      2   044303 044361
DATAN$/FOR54              1   007145 007273      2   044362 044444
DLOG10$/FOR54             1   007274 007304      2   044445 044450
SQRT$/FOR55               1   007305 007344      2   044451 044462
NEXP1$/FOR54              1   007345 007400      0   044463 044463
NIBUF$/FOR52              1   007401 007442
NERR$/FOR57-NUC           1   007443 010004      2   044464 044640
NSTOP$/NUC                1   010005 010030      2   044641 044647
```

Figure C.2. (Continued).

NIER$/FOR52	1	010031	010113	2	044650	044777
NOSYM$/FOR57	1	010114	010346	2	045000	045005
NINTR$/NUC	1	010347	010403	2	045006	045025
DATE-TIME/NUC-PACK	1	010404	010433	0	045026	045063
DSQRT$/FOR57	1	010434	010503	2	045064	045102
I1415S	1	010504	010746	0	045103	045126
	3	CS1415		2	BLANK$COMMON	
				4	CM1415	
DSHCH	1	010747	011005	0	045127	045143
				2	BLANK$COMMON	
LY3BY3	1	011006	011035	0	045144	045154
	3	CY3BY3		2	BLANK$COMMON	
CS1415 (COMMON BLOCK)					045155	045160
TP1415	1	011036	011602	0	045161	045245
	3	CS1415		2	BLANK$COMMON	
	5	CM1415		4	BASIC8	
				6	CZ3BY3	
CM1415 (COMMON BLOCK)					045246	045277
LS1415	1	011603	011651	0	045300	045312
	3	CM1415		2	BLANK$COMMON	
				4	CEGSFP	
DCSHCH	1	011652	011731	0	045313	045331
				2	BLANK$COMMON	
DCACSH	1	011732	012023	0	045332	045354
				2	BLANK$COMMON	
LZ3BY3	1	012024	012053	0	045355	045365
	3	CZ3BY3		2	BLANK$COMMON	
DCSNCS	1	012054	012136	0	045366	045404
				2	BLANK$COMMON	
LY2BY2	1	012137	012166	0	045405	045415
	3	CY2BY2		2	BLANK$COMMON	
RLIMMG	1	012167	012373	0	045416	045517
	3	CFMNPR		2	BLANK$COMMON	
	5	TOTL		4	PRTOFF	
	7	CDESGN		6	GMECIC	
DCANG1	1	012374	012532	0	045520	045542
				2	BLANK$COMMON	
DCSQRT	1	012533	012761	0	045543	045577
				2	BLANK$COMMON	
COMN26 (COMMON BLOCK)					045600	045613
CY3BY3 (COMMON BLOCK)					045614	045635
TYPE26	1	012762	013327	0	045636	045677
	3	BASIC8		2	BLANK$COMMON	
	5	COMN26		4	CY3BY3	
TYPE25	1	013330	013411	0	045700	045717
	3	BASIC8		2	BLANK$COMMON	
TYPE24	1	013412	013511	0	045720	045737
	3	BASIC8		2	BLANK$COMMON	
TYPE22	1	013512	013610	0	045740	045757
	3	BASIC8		2	BLANK$COMMON	
TYPE21	1	013611	013671	0	045760	045777
	3	BASIC8		2	BLANK$COMMON	
TYPE20	1	013672	014125	0	046000	046065
	3	BASIC8		2	BLANK$COMMON	
				4	CA2BY2	
CMN15C (COMMON BLOCK)					046066	046067
TYPE15	1	014126	014152	0	046070	046074

Figure C.2. (Continued).

	3	CMN15C	2	BLANK$COMMON
TYPE14	1	014153 014177	0	046075 046101
			2	BLANK$COMMON
CZ3BY3 (COMMON BLOCK)				046102 046123
TYPE11	1	014200 015214	0	046124 046214
	3	BASIC8	2	BLANK$COMMON
	5	CZ3BY3	4	COMN11
TYPE7	1	015215 016047	0	046215 046307
	3	BASIC8	2	BLANK$COMMON
TYPE2	1	016050 016405	0	046310 046430
	3	BASIC6	2	BLANK$COMMON
			4	CA2BY2
TYPE1	1	016406 016622	0	046431 046522
	3	BASIC6	2	BLANK$COMMON
			4	CA2BY2
CY2BY2 (COMMON BLOCK)				046523 046532
ATOY	1	016623 017130	0	046533 046562
	3	CA2BY2	2	BLANK$COMMON
			4	CY2BY2
AIOZ	1	017131 017355	0	046563 046621
	3	CA2BY2	2	BLANK$COMMON
			4	CZ2BY2
DACMUL	1	017356 017416	0	046622 046630
			2	BLANK$COMMON
BLDMTR	1	017417 017675	0	046631 046662
	3	PRTTUL	2	BLANK$COMMON
	5	CPRTIN	4	CATALG
	7	CMAGIC	6	CNMRDC
			8	CBLD
CMPZS	1	017676 017730	0	046663 046702
	3	BASIC6	2	BLANK$COMMON
			4	CMNZS
PRBFIT	1	017731 020073	0	046703 046746
	3	CPRBFT	2	BLANK$COMMON
POLEO	1	020074 020436	0	046747 047101
			2	BLANK$COMMON
PRMARI	1	020437 020544	0	047102 047141
	3	BASIC8	2	BLANK$COMMON
MTRMOV	1	020545 020613	0	047142 047157
			2	BLANK$COMMON
LZ2BY2	1	020614 020643	0	047160 047170
	3	CZ2BY2	2	BLANK$COMMON
LA2BY2	1	020644 020673	0	047171 047201
	3	CA2BY2	2	BLANK$COMMON
T11SBR	1	020674 021170	0	047202 047236
	3	COMN11	2	BLANK$COMMON
LDURIM	1	021171 021253	0	047237 047247
	3	DTASUB	2	BLANK$COMMON
CEGSFP (COMMON BLOCK)				047250 047255
LDSB11	1	021254 021322	0	047256 047270
	3	COMN11	2	BLANK$COMMON
			4	CEGSFP
MTRMUL	1	021323 021573	0	047271 047366
			2	BLANK$COMMON
DCMSOL (COMMON BLOCK)				047367 050004
DECOND (COMMON BLOCK)				050005 050006
VALDET (COMMON BLOCK)				050007 050012

Figure C.2. (Continued).

DECOMB	1	021574 023535	0	050013 050237
	3	VALDET	2	BLANK$COMMON
	5	DCMSCL	4	DECOND
DCRCIP	1	023536 023570	0	050240 050246
			2	BLANK$COMMON
DCMMUL	1	023571 023625	0	050247 050255
			2	BLANK$COMMON
DCMDIV	1	023626 023673	0	050256 050270
			2	BLANK$COMMON
FNDETR	1	023674 023751	0	050271 050301
	3	CATALG	2	BLANK$COMMON
TYPCAL	1	023752 024254	0	050302 050326
	3	CATALG	2	BLANK$COMMON
CASCDE	1	024255 024507	0	050327 050351
	3	CATALG	2	BLANK$COMMON
			4	CFLGAZ
FNDLCJ	1	024510 025007	0	050352 050400
	3	PRTTBL	2	BLANK$COMMON
			4	CATALG
FNDNET	1	025010 025160	0	050401 050423
	3	PRTTBL	2	BLANK$COMMON
CHKSTR	1	025161 025211	0	050424 050441
	3	DTATOT	2	BLANK$COMMON
AIDOD	1	025212 025403	0	050442 050464
			2	BLANK$COMMON
UPPTBL	1	025404 025575	0	050465 050507
	3	PRTTBL	2	BLANK$COMMON
			4	CUPTBL
UNPACK	1	025576 026361	0	050510 050615
	3	CPTWRD	2	BLANK$COMMON
PRCTLG	1	026362 026436	0	050616 050673
	3	CATALG	2	BLANK$COMMON
			4	DTASUB
PRPTBL	1	026437 026515	0	050674 050752
	3	PRTTBL	2	BLANK$COMMON
FNDHAM	1	026516 026561	0	050753 050763
	3	CATALG	2	BLANK$COMMON
TIME	1	026562 026610	0	050764 051010
			2	BLANK$COMMON
SRMIDB	1	026611 030154	0	051011 051365
	3	CATALG	2	BLANK$COMMON
	5	CRMRCT	4	BASICB
	7	SRCHSB	6	CMNZS
	9	CSRMTR	8	FLGSRH
	11	CFLGAZ	10	PRTOFF
FNDTMS	1	030155 030264	0	051366 051415
	3	CATALG	2	BLANK$COMMON
	5	PRTOFF	4	TOTMAS
FMFN	1	030265 030405	0	051416 051435
	3	CFMNPR	2	BLANK$COMMON
			4	CMNFMN
CMNZS (COMMON BLOCK)				051436 051441
CMPGAM	1	030406 030660	0	051442 051537
	3	CMNZS	2	BLANK$COMMON
	5	GMECIC	4	SRCHSB
	7	PRTOFF	6	PRGMTR
SRCHSB (COMMON BLOCK)				051540 051547

Figure C.2. (Continued).

LDAM2S	1	030661 031206	0	051550 051633
	3	CATALG	2	BLANK$COMMON
	5	CRMRC1	4	BASIC8
	7	FLGSRH	6	SRCHSB
	9	CFLGAZ	8	PRTOFF
PRINTR	1	031207 031313	0	051634 051661
			2	BLANK$COMMON
CZ2BY2 (COMMON BLOCK)				051662 051671
CA2BY2 (COMMON BLOCK)				051672 051701
ZTOA	1	031314 031540	0	051702 051740
	3	CA2BY2	2	BLANK$COMMON
			4	CZ2BY2
LOCMTR	1	031541 031615	0	051741 051752
	3	CATALG	2	BLANK$COMMON
FNDTL	1	031616 032022	0	051753 052014
	3	CATALG	2	BLANK$COMMON
	5	PRTOFF	4	TOTL
COMN11 (COMMON BLOCK)				052015 052055
LDDT11	1	032023 032460	0	052056 052236
	3	CATALG	2	BLANK$COMMON
	5	COMN11	4	DTASUB
			6	PRTOFF
RDCPRT	1	032461 033477	0	052237 052360
	3	CATALG	2	BLANK$COMMON
			4	CNMRDC
BLDKKL	1	033500 034111	0	052361 052445
	3	PRTTBL	2	BLANK$COMMON
	5	CNMRDC	4	CATALG
	7	CMAGIC	6	CPRT1N
			8	CFLGAZ
LDFREQ	1	034112 034142	0	052446 052461
	3	BASIC8	2	BLANK$COMMON
			4	PRTOFF
HEAD24	1	034143 034265	0	052462 052503
	3	CPTWRD	2	BLANK$COMMON
LD1MTR	1	034266 034356	0	052504 052527
			2	BLANK$COMMON
SKPLIN	1	034357 034411	0	052530 052537
			2	BLANK$COMMON
LOCNAM	1	034412 034454	0	052540 052551
	3	CATALG	2	BLANK$COMMON
ALUCAT	1	034455 034536	0	052552 052576
	3	CATALG	2	BLANK$COMMON
			4	DTASUB
LDDT7	1	034537 035437	0	052577 053036
	3	CATALG	2	BLANK$COMMON
	5	PRTOFF	4	DTASUB
LDDT4	1	035440 035732	0	053037 053127
	3	CATALG	2	BLANK$COMMON
	5	PRTOFF	4	DTASUB
LDDT1	1	035733 036327	0	053130 053247
	3	CATALG	2	BLANK$COMMON
	5	PRTOFF	4	DTASUB
LDPORT	1	036330 036652	0	053250 053337
	3	PRTTBL	2	BLANK$COMMON
			4	CPTWRD
STRLIN	1	036653 036667	0	053340 053363

Figure C.2. (Continued).

```
                                                              2    BLANK$COMMON
PAGE                             1    036670 036704           0    053364 053371
                                                              2    BLANK$COMMON
FLGSRH (COMMON BLOCK)                                              053372 053375
CRMRCT (COMMON BLOCK)                                              053376 053403
GMECIC (COMMON BLOCK)                                              053404 053423
CDESGN (COMMON BLOCK)                                              053424 053430
TOTMAS (COMMON BLOCK)                                              053431 053432
TOTL (COMMON BLOCK)                                                053433 053434
CSRHBC (COMMON BLOCK)                                              053435 053435
CMNFMN (COMMON BLOCK)                                              053436 053440
CFMNPR (COMMON BLOCK)                                              053441 053441
PRGMTR (COMMON BLOCK)                                              053442 053442
CSRMTR (COMMON BLOCK)                                              053443 053443
CUPTBL (COMMON BLOCK)                                              053444 053444
CPRBFT (COMMON BLOCK)                                              053445 053450
CSTACK (COMMON BLOCK)                                              053451 053451
CNMRDC (COMMON BLOCK)                                              053452 053453
CPRT1N (COMMON BLOCK)                                              053454 053455
CMAGIC (COMMON BLOCK)                                              053456 053456
CBLD (COMMON BLOCK)                                                053457 053457
CFLGAZ (COMMON BLOCK)                                              053460 053460
CPTWRD (COMMON BLOCK)                                              053461 053462
BASICB (COMMON BLOCK)                                              053463 053470
PRTOFF (COMMON BLOCK)                                              053471 053471
DTATOT (COMMON BLOCK)                                              053472 053472
DTASUB (COMMON BLOCK)                                              053473 053473
CATALG (COMMON BLOCK)                                              053474 054770
PRTTBL (COMMON BLOCK)                                              054771 057105
BLANK$COMMON (COMMON BLOCK)                                        057106 064155
CONTRL                           1    036705 040112           0    064156 064762
                                 3    CATALG                  2    BLANK$COMMON
                                 5    DTATOT                  4    BASICB
                                 7    TOTMAS                  6    TOTL
                                 9    CFMNPR                  8    PRTOFF
                                11    GMECIC                 10    CDESGN
                                13    CSRMTR                 12    CRMRCT
                                15    CMNFMN                 14    FLGSRH
BLKDTA                           3    PRTTBL                  2    BLANK$COMMON
                                 5    DTASUB                  4    CATALG
                                 7    PRTOFF                  6    DTATOT
                                 9    CPTWRD                  8    BASICB
                                11    CBLD                   10    CFLGAZ
                                13    CPRT1N                 12    CMAGIC
                                15    CSTACK                 14    CNMRDC
                                17    CUPTBL                 16    CPRBFT
                                19    PRGMTR                 18    CSRMTR
                                21    CMNFMN                 20    CFMNPR
                                                             22    CSRHBC

SYS$*RLIB$. LEVEL 57
END OF COLLECTION - TIME 4.807 SECONDS
```

Figure C.2. (Continued).

Figure C.2. (Continued).

```
SEADUCER RUN 80038 FOR TP-228 APPENDIX C                                        DATE 101972      PAGF   23

*******************************************************************************
 SEADUCER RUN 80038  APR 23,1970$ LIKE MOD 7 RUN 70335                 87 C-29
  DESIGN RUN $
 LINES OF CONSTANT TAIL LENGTH$
 CHARGE TO 16054501 BASELINE

 * * * * * BD  7 NETWORK TABLE

 S  1B7D,  -+1T1A,  -+1R2A,$
 S  2B7D,    1E2E,$
 S  3B7D,    2R2A,$
 S  4B7D,    1R2Z,$
 S  5B7D,    2Y2Z,$
 S  6B7D,  -+2E2E,    1V2W,   1Y2Z,$
 S  7B7D,  -+1T1B,    2H2Z,   2V2W,$

 * * * * * AD  6 NETWORK TABLE

 S  1A6D,    3C3D,$
 S  2A6D,    5B5D,$
 S  3A6D,  -+2C3D,    2B5D,$
 S  4A6D,  -+1B5D,    1C3D,$
 S  5A6D,  -+3B5D,    1R2D,$
 S  6A6D,  -+4B5D,    2R2D,$

 TYPE 1          RHO        AREA          ID       OD       LENGTH
 E2E1$         4416.90   .148261-01   .000000  .000000   .009070
                C REAL     C IMAG        C MULT                       MASS
               4820.00    .000000       .000000                      .59394

 TYPE 1          RHO        AREA          ID       OD       LENGTH
 R2A1$         7702.80   .790233-03   .000000  .000000   .007248
                C REAL     C IMAG        C MULT                       MASS
               4970.00    .000000       .000000                      .04412

 TYPE 1          RHO        AREA          ID       OD       LENGTH
 R2Z1$         7702.80   .790233-03   .000000  .000000   .000838
                C REAL     C IMAG        C MULT                       MASS
               4970.00    .000000       .000000                      .00510

 TYPE 1          RHO        AREA          ID       OD       LENGTH
 T2B1$         7730.00   .228639-02   .000000  .000000   .003357
                C REAL     C IMAG        C MULT                       MASS
               4970.00    .000000       .000000                      .05933

 TYPE 1          RHO        AREA          ID       OD       LENGTH
 T2B2$         7724.87   .168402-02   .000000  .000000   .003314
                C REAL     C IMAG        C MULT                       MASS
               4970.00    .000000       .000000                      .04311

 TYPE 1          RHO        AREA          ID       OD       LENGTH
```

Figure C.2. (Continued).

```
T2W3$          7719.24    .130699-02   .000000 .000000  .010215
               C REAL     C IMAG         C MULT                    MASS
               4970.00     .000000        .000000                  .10305

TYPE 1          RHO        AREA          ID       OD      LENGTH
I2W4$          7702.80    .790233-03   .000000 .000000  .006679
               C REAL     C IMAG         C MULT                    MASS
               4970.00     .000000        .000000                  .04066

TYPE 1          RHO        AREA          ID       OD      LENGTH
V2W1$          4416.90    .112776-01   .000000 .000000  .011370
               C REAL     C IMAG         C MULT                    MASS
               4820.00     .000000        .000000                  .56637

TYPE 1          RHO        AREA          ID       OD      LENGTH
V2W2$          4416.90    .112776-01   .000000 .000000  .011370
               C REAL     C IMAG         C MULT                    MASS
               4820.00     .000000        .000000                  .56637

TYPE 1          RHO        AREA          ID       OD      LENGTH
V2W3$          7788.46    .254984-02   .000000 .000000  .002224
               C REAL     C IMAG         C MULT                    MASS
               5116.00     .000000        .000000                  .04418

TYPE 1          RHO        AREA          ID       OD      LENGTH
Y221$          2702.81    .348119-02   .000000 .000000  .011370
               C REAL     C IMAG         C MULT                    MASS
               5200.00     .000000        .000000                  .10698

TYPE 1          RHO        AREA          ID       OD      LENGTH
Y222$          2702.81    .348119-02   .000000 .000000  .011370
               C REAL     C IMAG         C MULT                    MASS
               5200.00     .000000        .000000                  .10698

TYPE 4           UNIT MATRIX
Y223$              1.00
```

Figure C.2. (Continued).

```
TYPE 7          SCALE      MATRIX   NUMERATOR      DENOMINATOR      SYMMETRY
                FACTOR     FORM     ORDER          ORDER            FLAG
 Y224$          .1000+01   0        3              1                -1
         COEF. TO CHECK NEW TYPE 7
            POLYNOMIAL COEFFICIENTS FOR Z(I,J)=(C0+C1*F+...)/(D0+D1*F+...)

         NUMERATOR  POLYNOMIAL  COEFFICIENTS FOR MATRIX ELEMENT(  1,  1)
                .0000000000        -.8668996000+09
                .0000000000         .7711489900+05
                .0000000000        -.9040960000+01
                .0000000000         .1627919980-02

         DENOMINATOR POLYNOMIAL COEFFICIENTS FOR MATRIX ELEMENT(  1,  1)
                .0000000000         .0000000000
                .1000000000+01      .0000000000

         NUMERATOR  POLYNOMIAL  COEFFICIENTS FOR MATRIX ELEMENT(  1,  2)
                .0000000000         .8663080000+09
                .0000000000        -.7690410000+05
                .0000000000         .1246709980+02
                .0000000000        -.1630116980-02

         DENOMINATOR POLYNOMIAL COEFFICIENTS FOR MATRIX ELEMENT(  1,  2)
                .0000000000         .0000000000
                .1000000000+01      .0000000000

         NUMERATOR  POLYNOMIAL  COEFFICIENTS FOR MATRIX ELEMENT(  2,  2)
                .0000000000         .8691160000+09
                .0000000000        -.7743060000+05
                .0000000000        -.2671390000+00
                .0000000000        -.1807459980-02

         DENOMINATOR POLYNOMIAL COEFFICIENTS FOR MATRIX ELEMENT(  2,  2)
                .0000000000         .0000000000
                .1000000000+01      .0000000000

 F2S UNIT MATRIX
 D2S UNIT MATRIX
 S2S UNIT MATRIX
```

Figure C.2. (Continued).

```
 * * * * * F =    3500.000000 * * * * *


 TYPE 1          RHO        AREA          ID       OD       LENGTH
 T2A1$          7832.40    .217225-01    .000000  .000000   .038125
                C REAL     C IMAG        C MULT                         MASS
                5116.00     .000000       .000000                      6.48658

 REPLACE

 TYPE 1          RHO        AREA          ID       OD       LENGTH
 Y223$          2702.81    .245000-02    .000000  .000000   .035354
                C REAL     C IMAG        C MULT                         MASS
                5200.00     .000000       .000000                       .23411

 TYPE 11         RHO        AREA          ID       OD       LENGTH
 C3D$           7588.21    .490000-02    .000000  .000000   .013625
                C REAL     C IMAG        C MULT             N PIECES   MASS
                3743.27    .312617+01    .835144-03             2      1.01324

                         REAL               IMAG                MULT
            E33T     .1411660000+04    -.3416019970+01     .2419850000-02
            G33      .2452070000-01     .4595841239-05    -.1874270000-03
            S33D     .9404950000-11    -.1570899394-13     .1670290000-02

            K33      .6604539643+00    -.6940268089-04

 TOTAL LENGTH =  .061285 FOR SECTIONS   VW   EE   CD

 TYPE 1          RHO        AREA          ID       OD       LENGTH
 R2D1$          7702.80    .571140-03    .000000  .000000   .053199
                C REAL     C IMAG        C MULT                         MASS
                4970.00     .000000       .000000                       .23404
```

Figure C.2. (Continued).

Z SELF

MAG	ANG DEG	REAL	IMAG
.0000000000	.0000000000	.0000000000	.0000000000

	L T2A1	A C3D	T L C3D	NP	T MASS	T LENGTH	REACTOR	GAMMA IC	GAM EC MIN
T1C1	.038125	.004900	.173784	12	19.0963	.32423	.4270-01	.1106+08	.1037+03
T1C2	.038125	.006500	.208582	16	23.1521	.35903	.1997-01	.1231+08	.1373+03
T1C3	.038125	.007520	.225941	16	25.8822	.37639	.1774-01	.1263+08	.1578+03
T1C4	.038125	.008100	.234529	18	27.4699	.38498	.1313-01	.1271+08	.1693+03
T1C5	.038125	.012898	.282654	20	41.1598	.43310	.6547-02	.1210+08	.2626+03
T2C1	.076249	.004900	.129069	10	23.7235	.31764	.4755-01	.9667+07	.6358+02
T2C2	.076249	.006500	.161370	12	27.1023	.34994	.2907-01	.1171+08	.1153+03
T2C3	.076249	.007520	.178211	14	29.4351	.36678	.1945-01	.1249+08	.1355+03
T2C4	.076249	.008100	.186784	14	30.8118	.37536	.1842-01	.1279+08	.1470+03
T2C5	.076249	.012898	.238733	18	43.1544	.42731	.7201-02	.1291+08	.2434+03
T3C1	.114374	.004900	.109460	8	29.3947	.33616	.6387-01	.8577+07	.7236+02
T3C2	.114374	.006500	.138534	10	32.3620	.36523	.3691-01	.1077+08	.1007+03
T3C3	.114374	.007520	.153708	12	34.4156	.38041	.2364-01	.1176+08	.1189+03
T3C4	.114374	.008100	.161460	12	35.6304	.38816	.2252-01	.1219+08	.1293+03
T3C5	.114374	.012898	.209580	16	46.6595	.43628	.8462-02	.1328+08	.2202+03
T4C1	.152499	.004900	.098433	8	35.4228	.36326	.5775-01	.7851+07	.6559+02
T4C2	.152499	.006500	.125234	10	38.1342	.39006	.3383-01	.1002+08	.9124+02
T4C3	.152499	.007520	.139094	10	40.0041	.40392	.3140-01	.1105+08	.1076+03
T4C4	.152499	.008100	.146145	10	41.1083	.41097	.3002-01	.1154+08	.1171+03
T4C5	.152499	.012898	.189725	14	51.1155	.45455	.1045-01	.1329+08	.1998+03
T5C1	.190623	.004900	.091135	6	41.6058	.39408	.9532-01	.7333+07	.6097+02
T5C2	.190623	.006500	.116295	8	44.1404	.41924	.4949-01	.9430+07	.8459+02
T5C3	.190623	.007520	.129159	10	45.8799	.43211	.2951-01	.1047+08	.9955+02
T5C4	.190623	.008100	.135663	10	46.9044	.43861	.2827-01	.1096+08	.1081+03
T5C5	.190623	.012898	.175267	12	56.1233	.47821	.1359-01	.1311+08	.1831+03

LAST TIME INTERVAL = 21.635 SEC   TOTAL RUN TIME = 21.635 SEC

A Y2Z4

1	1	.9383815355+00	.0000000000
2	1	.0000000000	.5132157777-05
1	2	.0000000000	.5614587184+05
2	2	.7585939197+00	.0000000000

Z Y2Z4

1	1	.0000000000	-.1828434698+06
2	1	.0000000000	-.1948498163+06
1	2	.0000000000	.1948498163+06
2	2	.0000000000	.1478118859+06

Figure C.2. (Continued).

* * * * * COMMON PRT TBL * * * * *

N	NET SP	I SIGN C	D	J PORT	N PORTS	NET NAM	NUM APO	NUM NPO	N AHEAD	N BACK	LC J ROW
1	S	1	1	1	7	BD	1	-1	4	0	1
2	S	-1	1	1	1	TA	1	1	3	0	658
3	S	-1	1	1	2	RA	1	2	7	2	380
4	S	1	1	2	7	BD	2	-2	6	1	2
5	S	1	1	1	2	EE	2	4	13	7	341
6	S	1	1	3	7	BD	3	-3	8	4	3
7	S	1	1	2	2	RA	3	3	5	3	381
8	S	1	1	4	7	BD	4	-4	10	6	4
9	S	1	1	1	2	RZ	4	6	18	13	419
10	S	1	1	5	7	BD	5	-5	12	8	5
11	S	1	1	2	2	YZ	5	9	14	15	652
12	S	1	1	6	7	BD	6	-6	16	10	6
13	S	-1	1	2	2	EE	6	5	9	5	342
14	S	1	1	1	2	VW	6	10	19	11	566
15	S	1	1	1	2	YZ	6	8	11	18	651
16	S	1	1	7	7	BD	7	-7	20	12	7
17	S	-1	1	1	1	TB	7	12	0	19	862
18	S	1	1	2	2	RZ	7	7	15	9	420
19	S	1	1	2	2	VW	7	11	17	14	567
20	S	1	1	1	6	AD	1	-1	22	16	197
21	S	1	1	3	3	CD	1	3	28	25	1024
22	S	1	1	2	6	AD	2	-2	24	20	198
23	S	1	1	5	5	BD	2	8	32	34	670
24	S	1	1	3	6	AD	3	-3	27	22	199
25	S	-1	1	2	3	CD	3	2	21	29	1023
26	S	1	1	2	5	BD	3	5	31	28	867
27	S	1	1	4	6	AD	4	-4	30	24	200
28	S	-1	1	1	5	BD	4	4	26	21	866
29	S	1	1	1	3	CD	4	1	25	0	1022
30	S	1	1	5	6	AD	5	-5	33	27	201
31	S	-1	1	3	5	BD	5	6	34	26	868
32	S	1	1	1	2	RD	5	9	35	23	1091
33	S	1	1	6	6	AD	6	-6	0	30	202
34	S	-1	1	4	5	BD	6	7	23	31	869
35	S	1	1	2	2	RD	6	10	0	32	1092

Figure C.2. (Continued).

* * * * * COMMON CATALG * * * * *

I	NAME	MTR SIZ	I PC	N PC TOT	I TYPE	N. DT STR	LOC
1	BD	7	0	0	0	0	1
2	AD	6	0	0	0	0	197
3	EE	2	0	1	0	0	341
4	EE	2	1	1	1	7	357
5	RA	2	0	1	0	0	380
6	RA	2	1	1	1	7	396
7	RZ	2	0	1	0	0	419
8	RZ	2	1	1	1	7	435
9	TB	2	0	4	0	0	458
10	TB	2	1	4	1	7	474
11	TB	2	2	4	1	7	497
12	TB	2	3	4	1	7	520
13	TB	2	4	4	1	7	543
14	VW	2	0	3	0	0	566
15	VW	2	1	3	1	7	582
16	VW	2	2	3	1	7	605
17	VW	2	3	3	1	7	628
18	YZ	2	0	4	0	0	651
19	YZ	2	1	4	1	7	667
20	YZ	2	2	4	1	7	690
21	YZ	2	3	4	1	7	713
22	YZ	2	4	4	7	42	737
23	FS	2	0	0	0	0	795
24	DS	2	0	0	0	0	803
25	SS	2	0	0	0	0	811
26	TA	2	0	1	0	0	819
27	TA	2	1	1	1	7	835
28	TA	1	0	0	0	0	858
29	TB	1	0	0	0	0	862
30	BD	5	0	0	0	0	866
31	BD	0	0	0	0	0	966
32	BD	0	0	0	0	0	982
33	CD	3	0	0	11	33	1022
34	KD	2	0	1	0	0	1091
35	KD	2	1	1	1	7	1107
36	AD	2	0	0	0	0	1130
37	AD	0	0	0	0	0	1146
38	AD	0	0	0	0	0	1210
39	ES	2	0	0	0	0	1242
40	MS	2	0	0	0	0	1250
41	GS	2	0	0	0	0	1258
42	HS	2	0	0	0	0	1266

TOTAL DATA CELLS USED IN MASTER STORAGE 1273

Figure C.2. (Continued).

```
SEADUCER RUN 80038 FOR TP-22R APPENDIX C                                   DATE 101972        PAGE   30
LAST TIME INTERVAL =     .516 SEC          TOTAL RUN TIME =  22.151 SEC

@BRKPT   PRINT$


     RUNID:  M8003R    ACCOUNT: IEC17FF1CCEL    PROJECT: LMEHIF314522
       LOAD 9E3     9/M PRFILE        -1 M8003R
     M8003R*MSG: SC 2072
       BREAKPOINT IN THIS RUN
       LOAD 279     9/E B             -1 M8003R
       BREAKPOINT IN THIS RUN
     TIME: 00:00:22.901    IN: 334    OUT: L        PAGES:   39
     WDS XFRD(E2): 5753    I/O REFS: 1926    CORE SEC: 18.9
     INITIATION  TIME:    19:40:21-OCT 19,1972       VERSION:  2F.71.15R 10
     TERMINATION TIME:    19:45:42-OCT 19,1972
```

Figure C.2. (Continued).

APPENDIX D

SEARCH ROUTINE

INTRODUCTION

This appendix presents a description of the search procedure employed by the program for longitudinal vibrators. A detailed summary of naming conventions, equations, and user conventions presently existent in the search package is presented as well as a sample run. The procedure includes a decompaction process for a 3-3 mode ceramic stack.

The first step of this search procedure is the optional computation of a velocity control reactor with specified properties which maximizes the velocity control of the transducer element at a specified frequency. Following the loading of this reactor, the transducer element performance is computed at a number of frequencies over a band centered about a specified center frequency, f_O.

At each frequency within the frequency sweep, element performance is computed for each of a number of radiation boundary conditions by means of a boundary condition loop. Each performance variable is checked and only the maximum and minimum of each is stored. Several computed quantities are summed over the boundary condition loop, providing totals and averages. Following completion of the boundary condition loop, several quantities are computed for use later in computing two new quantities as a function of bandwidth about the center frequency. Also, selected performance variables are output at this point by printer, and either card punch or magnetic tape.

The process is then repeated at a new frequency until the entire frequency sweep is complete. Following completion of the frequency sweep, the two "FBAND" variables are computed as a function of bandwidth and output by specified means.

MECHANICAL NETWORK CONVENTIONS

All longitudinal resonator transducers using 3-3 mode ceramic may be compacted into three networks, as shown in figure D.1. The double arrow (⇒) defines the direction of positive power flow, and the current (velocity) is always in the clockwise direction. The following are descriptions of the basic networks and their ports:

Network A5S is defined as the compacted interconnection of networks B4S, C3S, and T1S. The standard interconnection table is

1	S	1A5S, 3C3S
2	S	2A5S, 3B4S
3	S	3A5S, 4B4S, 1T1S
4	S	4A5S, 1B4S, -+1C3S
5	S	5A5S, 2B4S, -+2C3S .

Network C3S is defined as the compacted (type 11) 3-3 mode ceramic stack, where, by convention,

1C3S is the ceramic mechanical port at the tail end,

2C3S is the ceramic mechanical port at the head end,

and 3C3S is the ceramic electrical port.

Network B4S is defined as the compacted and reduced interconnection of the remainder of the transducer, where, by convention,

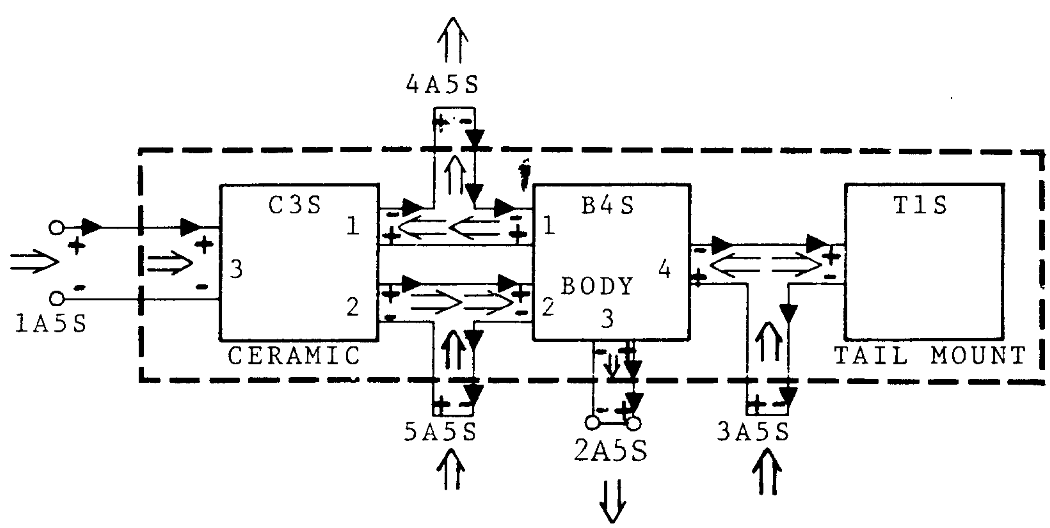


Figure D.1. Three Basic Networks for All Longitudinal Resonator Transducers.

1B4S is the mechanical port at the tail end of C3S,

2B4S is the mechanical port at the head end of C3S,

3B4S is the mechanical port at the radiating face,

and 4B4S is the mechanical port at the tail mount.

Network T1S is defined as the compacted and reduced interconnection of the tail mount assembly and is of the form of a complex passive tail impedance, Z_T.

ELECTRICAL NETWORK CONVENTIONS

The electrical network naming and sign conventions assumed by the procedure are presented in Figure D.2. Also shown are particular voltages (or forces) and currents (or velocities). The electrical networks are described as

Network S2S, the power amplifier;

Network A2S, the transducer element;

Network E2S, the velocity control network;

Network D2S and F2S, the matching networks;

Network G2S, $[A^{G2S}] \stackrel{d}{=} [A^{S2S}] * [A^{D2S}]$;

Network H2S, $[A^{H2S}] \stackrel{d}{=} [A^{F2S}] * [A^{A2S}]$;

and Network M2S, $[A^{M2S}] \stackrel{d}{=} [A^{D2S}] * [A^{E2S}] * [A^{F2S}]$;

where $[A^X]$ represents the A-form for a two-port network named X, and

$$\begin{bmatrix} E_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A \end{bmatrix} \begin{bmatrix} E_2 \\ I_2 \end{bmatrix} .$$

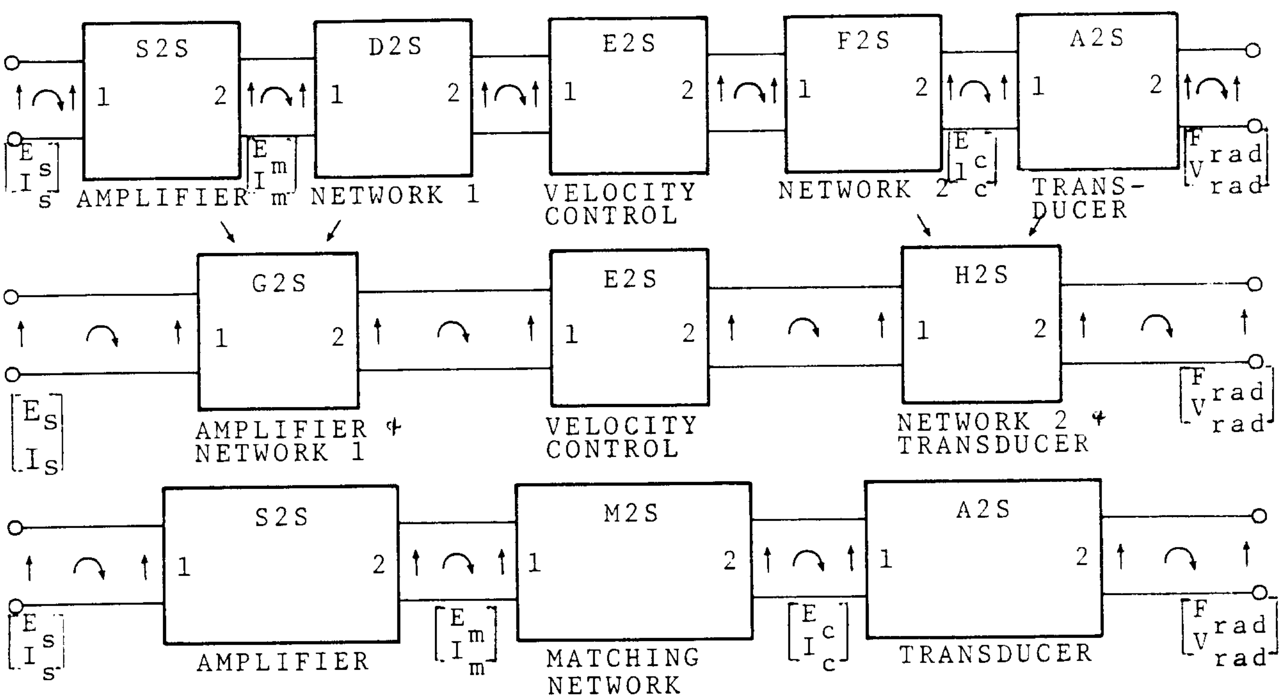


Figure D.2. Electrical Networks Assumed in the Search Procedure.

Similarly, the Z-form for a two-port network is defined by

$$\begin{bmatrix} E_1 \\ \\ E_2 \end{bmatrix} = \begin{bmatrix} \\ Z \\ \\ \end{bmatrix} \begin{bmatrix} I_1 \\ \\ I_2 \end{bmatrix} .$$

PORT VARIABLE DEFINITIONS

The following symbol definitions and relationships for port variables are made:

1. $f_{\ell i}, v_{\ell i}$ = force and velocity at the left (tail) end of ceramic piece #i.
2. f_{ri}, v_{ri} = force and velocity at the right (head) end of ceramic piece #i.
3. E_c, i_{ci} = voltage and current at the electrical port of ceramic piece #i.
4. F_L, V_L = force and velocity at Port #1C3S and Port #1B4S.
5. F_R, V_R = force and velocity at Port #2C3S and Port #2B4S.
6. E_C, I_C = voltage and current at Port #3C3S and Port #1A5S.
7. F_T, V_T = force and velocity at Port #4B4S.
8. $-F_T, V_T$ = force and velocity at Port #1T1S.
9. F_{rad}, V_{rad} = force and velocity at Port #3B4S and Port #2A5S.
10. $Z_{rad} \overset{d}{=} F_{rad}/V_{rad}$ = radiation impedance connected at 2A5S.
11. $Z_T \overset{d}{=} -F_T/V_T$ = tail impedance = Z^{T1S}; (Z_T = 0 for air termination).
12. E_S, I_S = voltage and current into power amplifier at 1S2S.
13. E_M, I_M = voltage and current into matched transducer at 1M2S.
14. $\begin{bmatrix} E_S \\ I_S \end{bmatrix} \overset{d}{=} \begin{bmatrix} A^{S2S} \end{bmatrix} \begin{bmatrix} E_M \\ I_M \end{bmatrix}$
15. $\begin{bmatrix} E_M \\ I_M \end{bmatrix} \overset{d}{=} \begin{bmatrix} A^{M2S} \end{bmatrix} \begin{bmatrix} E_C \\ I_C \end{bmatrix}$
16. $\begin{bmatrix} E_C \\ I_C \end{bmatrix} \overset{d}{=} \begin{bmatrix} A^{A2S} \end{bmatrix} \begin{bmatrix} F_{rad} \\ V_{rad} \end{bmatrix}$
17. $[A^{M2R}] \overset{d}{=} [A^{M2S}] * [A^{A2S}]$
18. $[A^{S2C}] \overset{d}{=} [A^{S2S}] * [A^{M2S}]$
19. $[A^{S2R}] \overset{d}{=} [A^{S2S}] * [A^{M2S}] * [A^{A2S}]$

20. $$\begin{bmatrix} f_{\ell i} \\ f_{ri} \\ E_c \end{bmatrix} \stackrel{d}{=} \begin{bmatrix} Z^C \end{bmatrix} \begin{bmatrix} V_{\ell i} \\ V_{ri} \\ i_{ci} \end{bmatrix}$$

21. $Z_{ec} \stackrel{d}{=} A_{12}^{S2R} / A_{11}^{S2R}$

$Z_{ic} \stackrel{d}{=} A_{22}^{S2R} / A_{21}^{S2R}$

22. $F_{ec} \stackrel{d}{=} 1/A_{11}^{S2R}$ * (a given voltage)

$F_{ic} \stackrel{d}{=} 1/A_{21}^{S2R}$ * (a given current)

23. $$\begin{bmatrix} F_L \\ F_R \\ E_C \end{bmatrix} \stackrel{d}{=} \begin{bmatrix} Z^{C3S} \end{bmatrix} \begin{bmatrix} V_L \\ V_R \\ I_C \end{bmatrix}$$

24. $$\begin{bmatrix} F_L \\ F_R \\ F_{rad} \\ F_T \end{bmatrix} \stackrel{d}{=} \begin{bmatrix} Z^{B4S} \end{bmatrix} \begin{bmatrix} V_L \\ V_R \\ V_{rad} \\ V_T \end{bmatrix}$$

PERFORMANCE VARIABLE DEFINITIONS

The performance variables are denoted by the following:

1. T^i_{33} = stress in the i^{th} ceramic piece at distance (χ) from the left (tail) end of the piece.
2. S^i_{33} = strain in the i^{th} ceramic piece at distance (χ) from the left (tail) end of the piece.
3. P^i_{LC} = power loss in the i^{th} ceramic piece (numbering from left (tail) to right (head)).
4. η^i_C = efficiency of the i^{th} ceramic piece.
5. E = electric field on the ceramic.
6. P_{LC} = total power loss in the ceramic stack.
7. η_C = total ceramic stack efficiency.
8. P_{LD} = total power loss in the electromechanical portion of the transducer.
9. η_D = total transducer electromechanical efficiency.
10. P_{LT} = total power loss excluding only the amplifier (including P_{TL}).
11. η_T = total efficiency excluding only the amplifier (including P_{TL}).
12. P_M = power into the tuned transducer (amplifier output).
13. P_C = power into the electromechanical portion of the transducer (into the ceramic).
14. P_{TL} = power output from the tail into the tail impedance.
15. P_{rad} = power output from the head into the medium (water).
16. Z_{ec} = voltage-velocity control impedance seen looking into the radiating face with port 1S2S short-circuited.

17. Z_{ic} = current-velocity control impedance seen looking into the radiating face with port 1S2S open-circuited.

18. Z_C = impedance seen looking into the ceramic port (Port 3C3S).

19. Z_M = impedance seen looking into the matching network (Port 1M2S).

20. Y_C = admittance equivalent to Z_C.

21. Y_M = admittance equivalent to Z_M.

22. P_{Arad} = total array output power.

23. P_{MA} = total array input power.

24. η_{TA} = total array efficiency excluding only the amplifiers.

25. x_i^T = the location of maximum stress magnitude in the i^{th} ceramic piece expressed as a distance from the left end.

26. x_i^S = the location of maximum strain magnitude in the i^{th} ceramic piece expressed as a distance from the left end.

27. Q_M = reactive power output by the amplifier.

28. P_{LM} = power loss in the electrical matching network, M2S.

29. η_M = efficiency of network M2S.

30. $|S_M|$ = complex power magnitude at port 1M2S (out of amplifier).

$$S_M = E_M \times I_M^* = \mathrm{Re}\,(E_M \times I_M^*) + j\mathrm{Im}\,(E_M \times I_M^*) = P_M + jQ_M$$

31. Z^M = reactor inserted to extremize $|\gamma_{ec}|$ or $|\gamma_{ic}|$ in midband logic.

USER INSTRUCTIONS

1. Specify interconnection table defining the BnS network which will be reduced to the B4S network.

2. Specify interconnection table defining the TmS network which will be reduced to the T1S network.

3. Specify all network parameters and types, including those for the Type 11 C3S network.

4. Specify $[A^{F2S}]$, $[A^{D2S}]$, $[A^{S2S}]$ and Zself.

5. Specify the midband logic parameters to be used in computing velocity control network matrix, $[A^{E2S}]$ (optional).

6. Specify the array of radiation impedance and velocity boundary conditions to be searched at each frequency.

7. Specify frequency range and frequency increment to be investigated.

8. Specify print, punch, and tape output options.

SEARCH PROCEDURE

The following paragraphs provide the basic equations and conventions found in the search procedure. The five basic operations are summarized below.

(Set frequency of maximum velocity control)
Midband logic procedure (optional)

(Enter frequency sweep)
Compaction

(Enter boundary condition loop)
Port variable computation
Performance variable computation

(Exit boundary condition loop – output results)

(Exit frequency sweep)
FBAND ZM

Midband Logic Procedure (Optional)

Single-reactor midband logic computes the series or parallel reactor Z^M, where $Q^M \overset{d}{=} \text{Imag}(Z^M)/\text{Real}(Z^M)$ and $R^M \overset{d}{=} \text{Real}(Z^M)$, required to extremize $|\gamma_{ec}|$ or $|\gamma_{ic}|$ at a specified frequency. If this subroutine is not called, $[A^{E2S}]$ is automatically set to a unit matrix and the following procedure is ignored.

1. Compute $[A^{G2S}]$ and $[A^{H2S}]$ from available information.

2. If $|Z_{ec}|$ is extremized, let i=1, j=1.

   If $|Z_{ic}|$ is extremized, let i=2, j=2.

   If Z^M = parallel reactor, let k=2, ℓ=1.

   If Z^M = series reactor, let k=1, ℓ=2, and compute the following constants:

   $$K_{11} = A^{G2S}_{i1} * A^{H2S}_{11} + A^{G2S}_{j2} * A^{H2S}_{21}$$

   $$K_{12} = A^{G2S}_{i1} * A^{H2S}_{12} + A^{G2S}_{j2} * A^{H2S}_{22}$$

   $$K_{21} = A^{G2S}_{ik} * A^{H2S}_{\ell 1}$$

   $$K_{22} = A^{G2S}_{ik} * A^{H2S}_{\ell 2}$$

   $$N_O = K_{k1}\, Z_{SELF} + K_{k2}$$

   $$N_1 = K_{\ell 1}\, Z_{SELF} + K_{\ell 2}$$

   $$D_O = K_{k1}$$

   $$D_1 = K_{\ell 1}$$

3. Compute reactor constants (caution: Q^M is always series).

$$M_0 = N_0 + R^M N_1$$

$$M_1 = jN_1 + N_1/Q^M$$

$$C_0 = D_0 + R^M D_1$$

$$C_1 = jD_1 + D_1/Q^M$$

$$\alpha_0 = |M_0|^2$$

$$\alpha_1 = 2\,(M_{0r} M_{1r} + M_{0i} M_{1i})$$

$$\alpha_2 = |M_1|^2$$

$$\beta_0 = |C_0|^2$$

$$\beta_1 = 2\,(C_{0r} C_{1r} + C_{0i} C_{1i})$$

$$\beta_2 = |C_1|^2$$

$$\delta_0 = (\alpha_1 \beta_0 - \alpha_0 \beta_1)$$

$$\delta_1 = 2\,(\alpha_2 \beta_0 - \alpha_0 \beta_2)$$

$$\delta_2 = (\alpha_2 \beta_1 - \alpha_1 \beta_2)$$

$$\epsilon_0 = (\beta_0 \delta_1 - 2\beta_1 \delta_0)$$

$$\epsilon_1 = (2\beta_0 \delta_2 - \beta_1 \delta_1 - 4\beta_2 \delta_0)$$

$$\epsilon_2 = (-3\beta_2 \delta_1)$$

$$\epsilon_3 = (-2\beta_2 \delta_2)$$

4. Compute reactor variables:

$$X^{\pm} = \frac{1}{2\delta_2}\left[-\delta_1 \pm \left(\delta_1^2 - 4\delta_2\,\delta_0\right)^{1/2}\right]$$

$$D^{\pm} = \frac{\epsilon_0 + \epsilon_1 X^{\pm} + \epsilon_2 (X^{\pm})^2 + \epsilon_3 (X^{\pm})^3}{\beta_0 + \beta_1 X^{\pm} + \beta_2 (X^{\pm})^2}$$

If $D^{\pm} < 0$, $X^{\pm}$ maximizes.

If $D^{\pm} > 0$, $X^{\pm}$ minimizes.

5. Select $x = x^{\pm}$ to maximize (or minimize).

If $x \geqslant 0$ set REACTOR FLAG = L ,

and REACTOR = x/ω.

If $x < 0$ set REACTOR FLAG = C,

and REACTOR = $-\dfrac{1}{\omega x}$.

6. Load A^{E2S} from following equations:

$$A_{11}^{E2S} = A_{22}^{E2S} = 1 + j\,0$$

If REACTOR FLAG = C, then $Z^M = R^M + \dfrac{1}{j\omega \text{ REACTOR}}\left(1 + \dfrac{j}{Q_M}\right)$.

If REACTOR FLAG = L, then $Z^M = R^M + j\omega \text{ REACTOR}\left(1 - \dfrac{j}{Q_M}\right)$.

If parallel reactor, then

$$A_{21}^{E2S} = 1/Z^M ,$$

and $$A_{12}^{E2S} = 0 .$$

If series reactor, then

$$A_{12}^{E2S} = Z^{M} \, .$$

and $$A_{21}^{E2S} = 0 \, .$$

Compaction

The following procedure is performed once at each new frequency within the frequency sweep.

1. Compute $[Z^{C3S}]$, $[Z^{B4S}]$, and $[Z^{T1S}]$.

2. Compute $[Z^{A5S}]$, $[Z^{A2S}]$, and $[A^{A2S}]$.

3. Compute left boundary condition matrix, $[K^{BCL}]$, where

$$[K^{BCL}] \stackrel{d}{=} - \begin{bmatrix} Z^{A5S}_{21} & Z^{A5S}_{23} & Z^{A5S}_{24} & Z^{A5S}_{25} \\ Z^{A5S}_{31} & Z^{A5S}_{33} & Z^{A5S}_{34} & Z^{A5S}_{35} \\ Z^{A5S}_{41} & Z^{A5S}_{43} & Z^{A5S}_{44} & Z^{A5S}_{45} \\ Z^{A5S}_{51} & Z^{A5S}_{53} & Z^{A5S}_{54} & Z^{A5S}_{55} \end{bmatrix} .$$

4. Compute the piece matrix, $[Z^C]$, where

$$Z^C_{11} = -Z^C_{22} = -j\rho cA \cot (k\ell) ,$$

$$Z^C_{12} = -Z^C_{21} = j\rho cA \csc (k\ell) ,$$

$$Z^C_{13} = Z^C_{31} = Z^C_{23} = -Z^C_{32} = -j \left(\frac{\rho c}{k}\right) g_{33} ,$$

and

$$Z^C_{33} = -j \frac{\rho c\ell}{kA} \left[g_{33} + S^D_{33}/\epsilon^T_{33}\right] .$$

Note: These equations are valid only for type 11 ceramic.

5. Compute right-handed decompaction matrix, $[K^{RC}]$, where

$$D \stackrel{d}{=} \left(Z^C_{13}\right)^2 + Z^C_{12} Z^C_{33} ,$$

$$K^{RC}_{11} = K^{RC}_{22} = \left[\left(Z^C_{13}\right)^2 - Z^C_{11} Z^C_{33}\right]/D ,$$

$$K^{RC}_{12} = -\left(Z^C_{11} + Z^C_{12}\right)\left[Z^C_{33}\left(Z^C_{12} - Z^C_{11}\right) + 2\left(Z^C_{13}\right)^2\right]/D ,$$

$$K^{RC}_{13} = -K^{RC}_{32} = Z^C_{13}\left(Z^C_{11} + Z^C_{12}\right)/D ,$$

$$K^{RC}_{21} = Z^C_{33}/D ,$$

$$K^{RC}_{23} = -K^{RC}_{31} = -Z^C_{13}/D ,$$

and $$K^{RC}_{33} = Z^C_{12}/D .$$

6. Compute $[A^{S2S}]$, $[A^{D2S}]$, $[A^{F2S}]$, $[A^{E2S}]$, and $[A^{M2S}]$.

7. Compute Z_{ec} and Z_{ic} from definitions. Then,

$$\gamma_{ec} = Z_{SELF} + Z_{ec} ,$$

$$\gamma_{ic} = Z_{SELF} + Z_{ic} ,$$

where Z_{SELF} is self impedance.

Port Variable Computation

The following procedure is used in computing the port variables for every network involved in the interconnection (decompaction) and is performed for a single radiation boundary condition within the boundary condition loop.

1. Compute $[K^{BCR}]$, the right boundary condition vector, where

$$[K^{BCR}] \stackrel{d}{=} \begin{bmatrix} Z_{22}^{A5S} - Z_{rad} \\ Z_{32}^{A5S} \\ Z_{42}^{A5S} \\ Z_{52}^{A5S} \end{bmatrix} * V_{rad} .$$

2. Solve

$$[K^{BCL}] \begin{bmatrix} I_C \\ V_T \\ V_L \\ V_R \end{bmatrix} = [K^{BCR}] \text{ for} \begin{bmatrix} I_C \\ V_T \\ V_L \\ V_R \end{bmatrix} .$$

3. Compute

$$\begin{bmatrix} F_L \\ F_R \\ E_C \end{bmatrix} = [Z^{C3S}] \begin{bmatrix} V_L \\ V_R \\ I_C \end{bmatrix} .$$

4. Compute $F_T = -Z^{T1S} V_T$.

5. Compute $\begin{bmatrix} E_M \\ I_M \end{bmatrix} = [A^{M2S}] \begin{bmatrix} E_C \\ I_C \end{bmatrix}$.

6. Compute $\begin{bmatrix} E_S \\ I_S \end{bmatrix} = [A^{S2S}] \begin{bmatrix} E_M \\ I_M \end{bmatrix}$.

7. For each ceramic piece in the stack, compute

$$\begin{bmatrix} f_{ri} \\ v_{ri} \\ i_{ci} \end{bmatrix} = [K^{RC}] \begin{bmatrix} f_{\ell i} \\ v_{\ell i} \\ E_C \end{bmatrix} \text{for the } i^{th} \text{ ceramic piece.}$$

where

$$\begin{bmatrix} f_{ri} \\ v_{ri} \end{bmatrix} \underline{\underline{d}} \begin{bmatrix} f_{\ell,\, i+1} \\ v_{\ell, i+1} \end{bmatrix}$$

$$\begin{bmatrix} f_{\ell 1} \\ v_{\ell 1} \end{bmatrix} = \begin{bmatrix} F_L \\ V_L \end{bmatrix}.$$

Performance Variable Computation

The following procedure is used to compute the performance variables from a single set of port variables.

All performance variables are searched for both maxima and minima over the specified boundary conditions at each frequency except for the cumulative array performance variables of Step 12.

1. Compute

$$\begin{bmatrix} F_L \\ F_R \end{bmatrix} = \begin{bmatrix} f_{\ell 1} \\ f_{\ell N} \end{bmatrix}$$

$$\begin{bmatrix} V_L \\ V_R \end{bmatrix} = \begin{bmatrix} v_{\ell 1} \\ v_{\ell N} \end{bmatrix}$$

where N is total number of ceramic pieces.

2. $$|T^i_{33}|_{max} = \mathrm{MAX}\left[|T^i_{33}|_{X=0}, |T^i_{33}|_{X=\ell}, |T^i_{33}|_{X=x^T_{pi}} \right]$$

x^T_i = location of $|T^i_{33}|_{max}$.

3. $$|S^i_{33}|_{max} = \mathrm{MAX}\left[|S^i_{33}|_{X=0}, |S^i_{33}|_{x=\ell}, |S^i_{33}|_{X=x^S_{pi}} \right]$$

x^S_i = location of $|S^i_{33}|_{max}$.

4. $$\mathrm{Re}\left(E_C\, i^*_{ci}\right) = \mathrm{Re}\,(E_C) * \mathrm{Re}\,(i_{ci}) + \mathrm{Im}\,(E_C) * \mathrm{Im}\,(i_{ci})$$

5. $$P^i_{\ell c} = \mathrm{Re}\left(E_C\, i^*_{ci} + f_{\ell i}\, v^*_{\ell i} - f_{\ell i+1}\, v^*_{\ell i+1}\right)$$

6. $$\eta^i_C = 100\% * \left[1 - \frac{P^i_{\ell c}}{\mathrm{Re}\left(E_C\, i^*_{ci}\right)} \right]$$

7. Search over all ceramic pieces for these ceramic variables.

$$T^M = \text{MAX}\left[|T^i_{33}|_{max}, i=1, \ldots, N\right]$$

$$S^M = \text{MAX}\left[|S^i_{33}|_{max}, i=1, \ldots, N\right]$$

$$P^M_{\ell c} = \text{MAX}\left[p^i_{\ell c}, i=1, \ldots, N\right]$$

$$\eta^N_C = \text{MIN}\left[\eta^i_C, i=1, \ldots, N\right]$$

and $$i^M_C = \text{MAX}\left[i_{ci}, i=1, \ldots, N\right] .$$

8. Compute exterior ceramic stack performance variables.

$$P_{LC} = \text{Re}\left(F_L V^*_L + E_C I^*_C - F_R V^*_R\right)$$

$$P_C = \text{Re}\left(E_C I^*_C\right)$$

$$E = E_C/\ell \; ; \; \ell = \text{ceramic piece length}$$

$$Z_C = E_C/I_C$$

$$Y_C = I_C/E_C$$

9. Compute exterior electromechanical performance variables.

$$P_{TL} = -\mathrm{Re}\left(Z_T V_T V_T^*\right)$$

$$P_{rad} = \mathrm{Re}\,(Z_{rad} V_{rad} V_{rad}^*)$$

10. Compute amplifier boundary condition performance variables.

$$P_M = \mathrm{Re}\left(E_M I_M^*\right)$$

$$Q_M = \mathrm{Im}\left(E_M I_M^*\right)$$

$$|S_M| = \left(P_M^{\,2} + Q_M^{\,2}\right)^{1/2}$$

$$Z_M = E_M/I_M$$

$$Y_M = I_M/E_M$$

11. Compute transducer performance variables.

$$P_{LT} = \mathrm{Re}\left(E_M I_M^*\right) - \mathrm{Re}\left(Z_{rad} V_{rad} V_{rad}^*\right) = P_M - P_{rad}$$

$$\eta_T = 100\% * (1 - P_{LT}/P_M)$$

$$V/E_s = V_{rad}/E_s \qquad P_{rad}/|E_s|^2$$

$$V/I_s = V_{rad}/I_s \qquad P_{rad}/|I_s|^2$$

12. Cumulative array performance variables are these:

$$P_{MA} = \sum P_M ,$$

$$P_{Arad} = \sum P_{rad} ,$$

and $$\eta_{TA} = 100\% * (P_{Arad}/P_{MA}) .$$

FBAND ZM

Following completion of the frequency sweep, the ratio of ZM MAX/MIN is computed (magnitude and angle) as a function of bandwidth (in Hz) centered about a specified center frequency. The following procedure is used.

1. FBAND $|Z_M|$

   This performance parameter is defined in the following manner:

   Given: f_0 = center frequency of the operating band.

   $f_0 + f_1, f_0 - f_1$ = edge frequencies of band BW_1.

   $|Z_M| \max_1$ = max mag ZM in band BW_1.

   $|Z_M| \min_1$ = min mag ZM in band BW_1.

   Thus, FBAND MAG ZM $\stackrel{d}{=} \dfrac{|Z_M| \max_1}{|Z_M| \min_1}$ at $BW = BW_1 = 2f_1$.

   Similarly for BW_i between $f_0 + f_i$ and $f_0 - f_i$, FBAND MAG ZM_i is computed. f_i is stepped from zero to one-half of operating band.

   FBAND MAG ZM is to be plotted against BW and not FREQ.

2. FBAND$\angle Z_M$

   This performance parameter is defined in similar manner to the foregoing:

   Given: $f_0, f_0 + f_1, f_0 - f_1$, BW, $(\angle Z_M) \max_1, (\angle Z_M) \min_1$ as before.

   Thus, FBAND ANG ZM = $(\angle Z_M) \max_1 - (\angle Z_M) \min_1$ at $BW = BW_1$.

   FBAND ANG ZM is plotted against BW also; but the units are "degrees" instead of "unitless ratio" as was the case above.

Ceramic Stress And Strain

The following development provides a detailed documentation of the methods required in D.6.5, steps 2 and 3 to compute stress and strain existent at the interior of a ceramic piece. The symbols used here are defined in Appendix B.

1. The stress in the i^{th} ceramic piece at a distance χ from the left edge of the piece is given by this expression:

$$T_{33}^{i} = K_1' + K_2' \cos k\chi + K_3' \sin k\chi ,$$

where

$$K_1' = j \frac{g_{33}\, i_{ci}}{\omega A\, s_{33}^{D}} ,$$

$$K_2' = -j\rho c \left[V_{\ell,i+1} \csc k\ell - V_{\ell i} \cot k\ell \right] ,$$

$$K_3' = j\rho c\, V_{\ell i} ,$$

and $$k = \omega / C .$$

Assuming that higher order terms may be neglected (i.e., small angle approximation), then

$$T_{33}^{i} \approx K_0^T + K_1^T \chi + K_2^T \chi^2 ,$$

where

$$K_0^T = K_1' + K_2' = K_{0r}^T + j\, K_{0i}^T ,$$

$$K_1^T = k\, K_3' = K_{1r}^T + j\, K_{1i}^T ,$$

and $$K_2^T = -1/2\, k^2 K_2' = K_{2r}^T + j\, K_{2i}^T .$$

Differentiating $|T_{33}^i|^2$, equating to zero, and solving for χ we find that

$$\chi = \chi_p^T = -1/2 \frac{M_1^T}{M_2^T},$$

where

$$M_0^T = |K_0^T|^2 ,$$

$$M_1^T = 2\left(K_{0r}^T K_{1r}^T + K_{0i}^T K_{1i}^T\right),$$

and $$M_2^T = |K_1^T|^2 + 2\left(K_{0r}^T K_{2r}^T + K_{0i}^T K_{2i}^T\right).$$

2. The strain in the i^{th} ceramic piece at distance χ from the left edge of the piece is given by

$$S_{33}^i = (K_2' \cos k\chi + K_3' \sin k\chi)\left(s_{33}^D\right) .$$

By again making the small angle approximation, differentiating $|S_{33}|^2$, and equating to zero, one finds

$$\chi = \chi_p^S = -1/2 \frac{M_1^S}{M_2^S},$$

where

$$M_0^S = |K_0^S|^2 .$$

$$M_1^S = 2\left(K_{0r}^S K_{1r}^S + K_{0i}^S K_{1i}^S\right),$$

$$M_2^S = |K_1^S|^2 + 2\left(K_{0r}^S K_{2r}^S + K_{0i}^S K_{2i}^S\right),$$

$$K_0^S = K_2' s_{33}^D = K_{0r}^S + j K_{0i}^S .$$

$$K_1^S = K_1^T s_{33}^D = K_{1r}^S + j K_{1i}^S .$$

and

$$K_2^S = K_2^T s_{33}^D = K_{2r}^S + j K_{2i}^S .$$

3. Search procedure for maximum and minimum values of $|T_{33}|$ and $|S_{33}|$. If χ_p^S or χ_p^T falls outside of $[0, \ell]$ inclusive, then discard that particular value. Otherwise, compute

$$|T_{33}|_{X=0} = \left(M_0^T\right)^{1/2}$$

$$|S_{33}|_{X=0} = \left(M_0^S\right)^{1/2}$$

$$|T_{33}|_{X=\ell} = |K_1' + (K_2' \cos k\ell + K_3' \sin k\ell)|$$

$$|S_{33}|_{X=\ell} = |s_{33}^D (K_2' \cos k\ell + K_3' \sin k\ell)|$$

$$|T_{33}|_{X=\chi_p^T} = |K_1' + K_2' \cos\left(k\,\chi_p^T\right) + K_3' \sin\left(k\,\chi_p^T\right)| \text{ if } 0 \leqslant \chi_p^T \leqslant \ell$$

$$|S_{33}|_{X=\chi_p^T} = |s_{33}^D * \left(K_2' \cos\left(k\,\chi_p^S\right) + K_3' \sin\left(k\,\chi_p^S\right)\right)| \text{ if } 0 \leqslant \chi_p^S \leqslant \ell .$$

SUMMARY

To summarize the requirements of the search procedure, the user must specify

(1) the interconnection table that defines the BnS network, which will be reduced to the B4S network,

(2) the interconnection table that defines TmS network, which will be reduced to the T1S network.

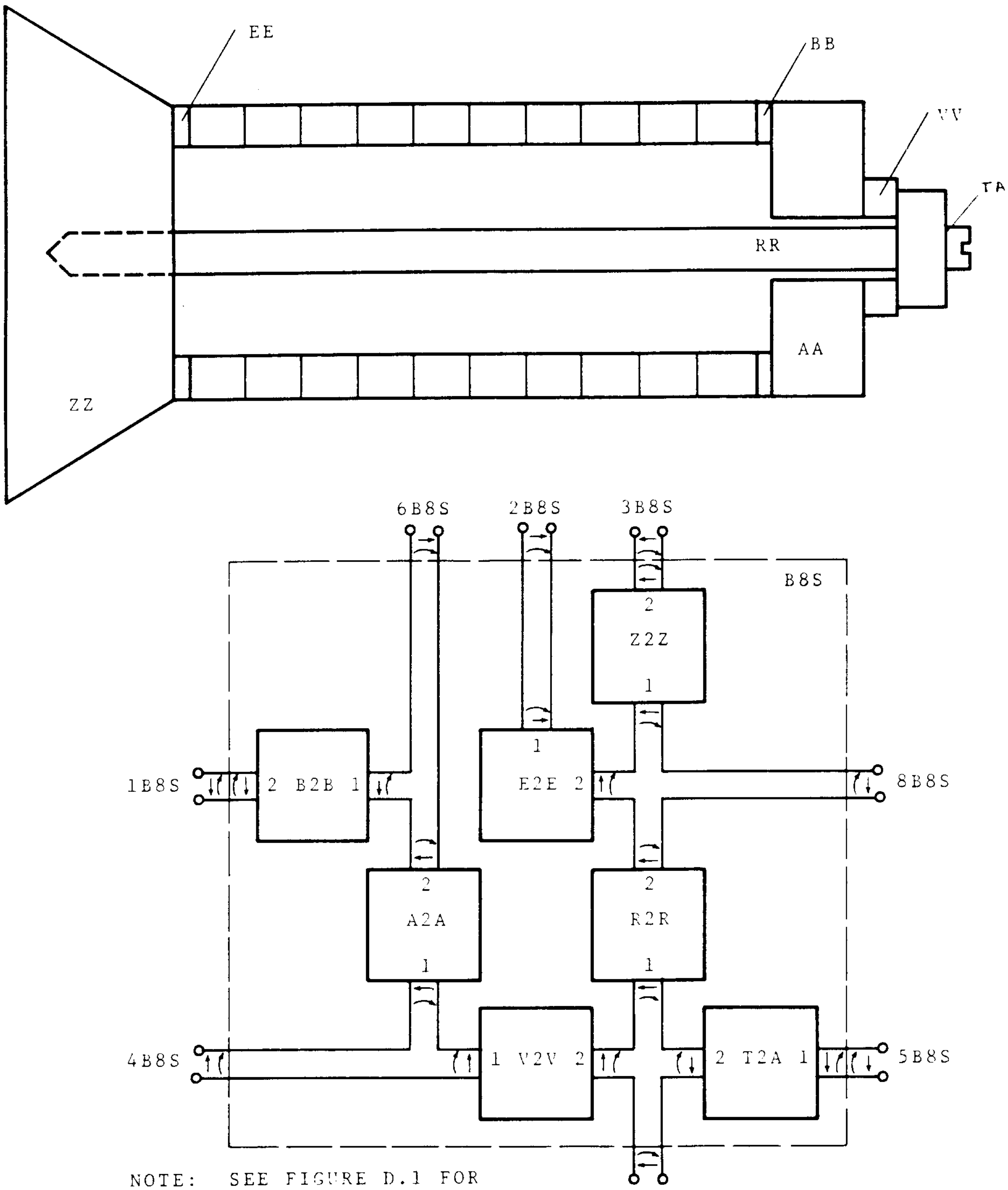
(3) $[A^{F2S}]$, $[A^{D2S}]$, and $[A^{S2S}]$, which can be done either through interconnection tables or constants, and

(4) the frequency range and frequency increment to be investigated.

He must also input an array of radiation impedances.

SAMPLE SEARCH ROUTINE

Figure D.3 shows a diagram of the transducer element used in the search example: a listing of the control program and associated printed output is shown in figure D.4. Computer-generated plots from the search procedure are shown in figure D.5.



NOTE: SEE FIGURE D.1 FOR REMAINING INTERCONNECTION SCHEMATIC.

Figure D.3. Transducer Diagram And Interconnection Schematic.

Figure D.4.

Listing and Output of the Control Routine Used in a Search Procedure

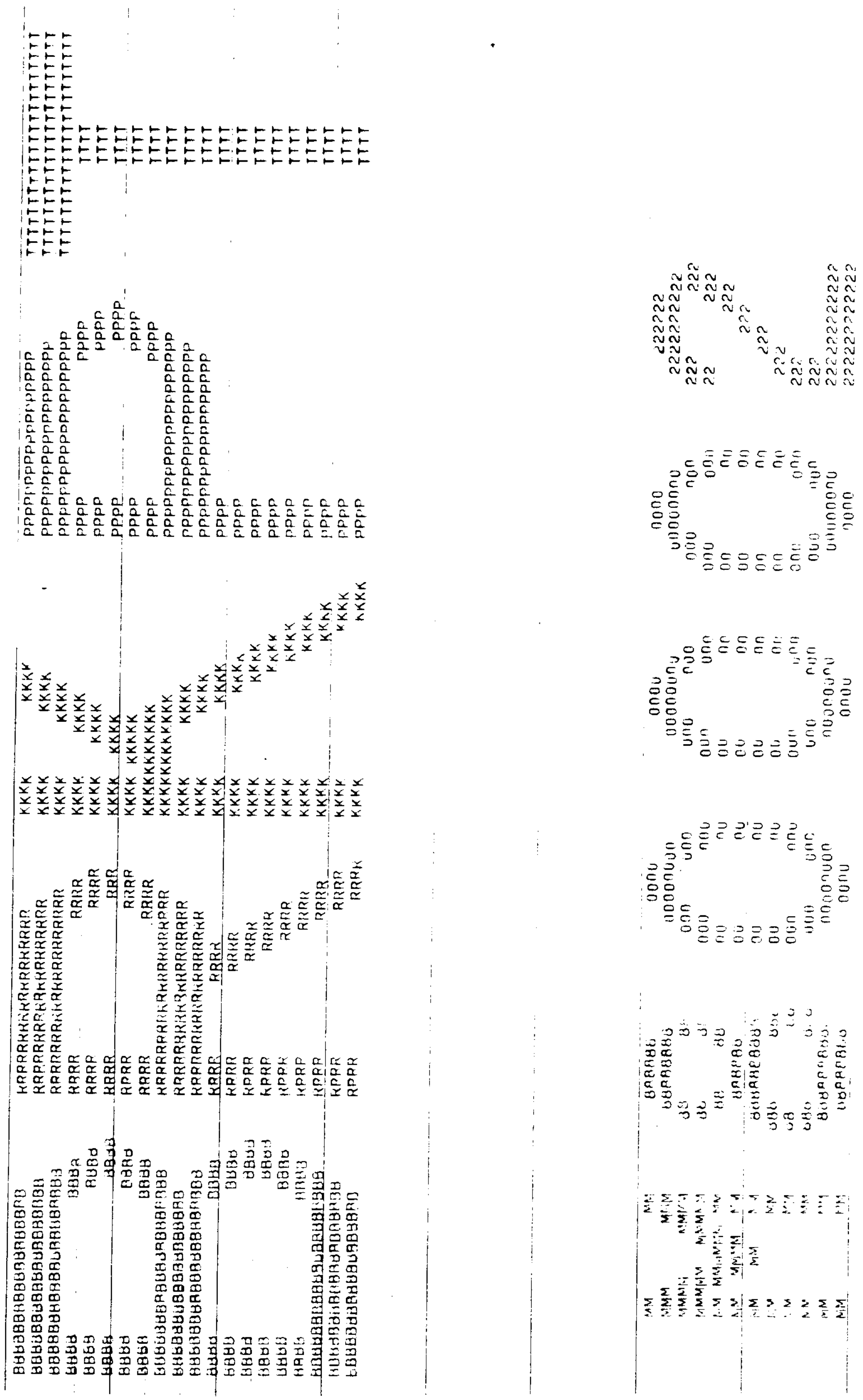


Figure D.4. (Continued).

```
SEADUCER RUN 80002 FOR TP-22P APPL LIA D                                    DATE 102072        PAGE      1

@COPIN B.,TPF$.
FURPUR 023A-10/20-10:21
 112 SYM  112 REL


@FREE   B.


@ASG,T 14,T,P80002
```

Figure D.4. (Continued).

```
SEADUCER RUN 80002 FOR TP-228 APPENDIX D                                                    DATE 102072        PAGE     2

WFOR,IS    CONTPL,CONTRL
FOR 0010-10/20/72-10:25:45 (,0)

   MAIN PROGRAM

   STORAGE USED: CODE(1) 000563; DATA(0) 000374; BLANK COMMON(2) 004704

    COMMON BLOCKS:

    0003   BASIC8 000006
    0004   DTATOT 000001

   EXTERNAL REFERENCES (BLOCK, NAME)

    0005   SETCLK
    0006   PAGE
    0007   STRLIN
    0010   LDPORT
    0011   LDDT1
    0012   LDDT2
    0013   LDDT5
    0014   LDDT11
    0015   ENDIMS
    0016   ALOCAT
    0017   LOCNAM
    0020   SKPLIN
    0021   LDIMTR
    0022   HEAD24
    0023   PREPZV
    0024   SRMIDR
    0025   TIME
    0026   FSRCH
    0027   PRPTBL
    0030   PPCTLG
    0031   NINTR$
    0032   NPRT$
    0033   NIO2$
    0034   NWDU$
    0035   NSTOP$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000   000023 5F      0002 D 000000 DATA     0003 D 000000 DF       0000 D 000000 DFBAND   0003 D 000002 DOMEGA
    0003 D 000004 DPI     0000 D 000004 DQM      0000 D 000002 DRM      0000 I 000007 ID2S     0000 I 000016 IFARAY
    0000 I 000006 IF2S    0000 I 000017 INZVUN   0000 I 000021 IOUTOP   0000 I 000020 IOUTUN   0000 I 000010 IS2S
    0000 I 000022 IUNITT  0017 I 000000 LOCNAM   0004 I 000000 MXDATA   0000 I 000015 NARRAY   0000 R 000011 RHOCA
    0000 R 000012 SCF     0000 R 000014 SCV      0000 R 000013 SCZ


 00101      1*          DOUBLE PRECISION DATA                                            CONTRL
 00103      2*          DOUBLE PRECISION DF, DOMEGA, DPI                                 CONTRL
 00104      3*          DOUBLE PRECISION DFBAND, DRM, DQM                                CONTRL
 00105      4*          COMMON / BASIC 8 / D F, D OMEGA, D PI
```

Figure D.4. (Continued).

```
00106   COMMON / DTA TOT / MX DATA
00107   COMMON /         / DATA(1250)
00110   MX DATA = 1250
00111
00111   CALL SETCLK
00112   CALL PAGE
00113   CALL STR LIN
00114   PRINT 5
00116 5 FORMAT(' SEADUCER RUN 80002 MAY 13,1970 $ (LIKE MOD 7 RUN 70451)'/
00116  /        ' MODEL 451 $'/
00116  /        ' SEARCH $'/
00116  /        ' CHARGE TO 16054501 TRANSMIT TECHNOLOGY' )
00117
00117   CALL LD PORT( 'S', '1B8S, 2B2B,$' )
00120   CALL LD PORT( 'S', '2B8S, 1E2E,$' )
00121   CALL LD PORT( 'S', '3B8S, 2Z2Z,$' )
00122   CALL LD PORT( 'S', '4B8S, 1A2A, 1V2V,$' )
00123   CALL LD PORT( 'S', '5B8S, 1T2A,$' )
00124   CALL LD PORT( 'S', '6B8S, 1R2B, -+2A2A,$' )
00125   CALL LD PORT( 'S', '7B8S, 1R2H, -+2V2V, -+2T2A,$' )
00126   CALL LD PORT( 'S', '8B8S, 1Z2Z, -+2E2E, -+2R2R,$' )
00127
00127   CALL LD PORT('S', '1T1S, 121T,$' )
00130
00130   CALL LD PORT( 'S', '1A5S, 3C3S,$' )
00131   CALL LD PORT( 'S', '2A5S, 3R4S,$' )
00132   CALL LD PORT( 'S', '3A5S, 4B4S, 1T1S,$' )
00133   CALL LD PORT( 'S', '4A5S, 1R4S, -+1C3S,$' )
00134   CALL LD PORT( 'S', '5A5S, 2R4S, -+2C3S,$' )
00135
00135   CALL LD DT 1
00135  / ('A2A1$',7656., .821425E-2,1.618E-2,0., 4.490725E-2, 5120.,0.,0.)
00136   CALL LD DT 1
00136  / ('B2B1$',7856., .544568E-2,0.,10.16E-2, .4316E-2, 5120.,0.,0.)
00137   CALL LD DT 1
00137  / ('E2E1$',7656., .544568E-2,0.,10.16E-2, .4316E-2, 5120.,0.,0.)
00140   CALL LD DT 1
00140  / ('V2V1$',7656., .0617787E-2,1.618E-2,0., .404812E-2, 5120.,0.,0.)
00141   CALL LD DT 1
00141  / ('T2A1$',7656., .0173586E-2,0.,0., 1.5113E-2, 5120.,0.,0.)
00142   CALL LD DT 1
00142  / ('T2A2$',7656., .0601728E-2,0.,0., 1.61925E-2, 5120.,0.,0.)
00143
00143   CALL LD DT 1
00143  / ('R2R1$',7656., .0173586E-2,0.,0., .65E-2, 5120.,0.,0.)
00144   CALL LD DT 1
00144  / ('R2R2$',7656., .0205929E-2,0.,0., 25.7334E-2, 5120.,0.,0.)
00145   CALL LD DT 1
00145  / ('R2R3$',7656., .0173586E-2,0.,0., .65E-2, 5120.,0.,0.)
00146
00146   CALL LD DT 1
00146  / ('Z2Z1$',2635., .816851E-2,0.,0., .6477E-2, 4950.,0.,0.)
00147   CALL LD DT 2('Z2Z2$', 2635.,1.28476E-2,0.,0., 2.62197E-2,0.,0.,
00147  /             5.8293E-2,4950.,0.,0.)
00150   CALL LD DT1('Z2Z3$',2635.,2.62197E-2,0.,0.,1.61925E-2,4950.,0.,0.)
00151
00151   CALL LD DT 5('Z1T $', 0., 0. )
```

Figure D.4. (Continued).

```
SEADUCER RUN 80002 FOR TP-228 APPENDIX D                                        DATE 102072        PAGE    4

00152            CALL LD DT 11('C35$',10,7793.9,.269172E-2,0.,10.16E-2,2.16742E-2,
00152           / .128036D4, 0.D0, .2288D-2,  .227984D-1, 0.D0, -.7651D-3,
00152           / .102055D-10, 0.D0, .2431D-2 )
00153            CALL FNDTMS
00154
00154            CALL ALOCAT('FS', 2, 8)
00155            IF2S = LOC NAM('FS')
00156            CALL ALOCAT('DS', 2, 8)
00157            ID2S = LOC NAM('DS')
00160            CALL ALOCAT( 'SS', 2, 8)
00161            IS2S = LOC NAM('SS')
00162            CALL SKP LIN(1)
00163            CALL LD I STR(IF2S, 2)
00164            CALL HEAD 24(' F2S UNIT MATRIX        ')
00165            CALL LD I STR(ID2S, 2)
00166            CALL HEAD 24(' D2S UNIT MATRIX        ')
00167            CALL LD I STR(IS2S, 2)
00170            CALL HEAD 24(' S2S UNIT MATRIX        ')
00171
00171       C * * * * * ARRAY 31,32,33 CONVERSIONS * * * * *
00171            RHOCA = 1025. * 1525. * (7.5*.0254)**2
00172            SCF = 1.2
00173            SCZ = RHOCA/SCF**2
00174            SCZ = RHOCA*.7225
00175            SCV = .0254
00176            N ARRAY = 32
00177            IF ARAY = 2500
00200            IN ZV UN = 5
00201            I OUT UN = 4)
00202            I OUT UN = 20
00203            CALL PREP ZV(N ARRAY, IF ARAY, IN ZV UN, I OUT UN, SCF, SCZ, SCV)   EXEC 8
00204
00204            DRM = 1.D-30
00205            DQM = 1.D30
00206            DFBAND = 3420.
00207            CALL SP MIFB(DFBAND,  'MAX', 'IC', 'P', DRM, DQM )
00210            CALL TIME
00211            I OUT OP = 1
00212            I OUT OP = 2
00213            I UNIT T = 4
00214            I UNIT T = 6
00215            I UNIT T = 14                                                       EXEC 8
00216            IF ( I UNIT T .NE. 0 ) WRITE(I UNIT T,  5 )
00221            CALL F SRCH(3400, 3500,  20, IOUTOP, I UNIT T, 'LBL1', 'LBL2')
00222            CALL TIME
00223
00223            CALL PAGE
00224            CALL PR PTPL
00225            CALL PAGE
00226            CALL PR CTLC
00227            CALL PAGE
00230            CALL TIME
00231            STOP
00232            END

         END OF COMPILATION:        NO DIAGNOSTICS.
```

Figure D.4. (Continued).

@TOP TIME: 10:25:53 DATE: 20 OCT 72 CPU TIME (MILSEC): 2547

@PREP TPF$
FURPUR 023A-10/20-10:25

@PRT,T TPF$.

LM6010314522*TPF$. ELEMENT TABLE

D	NAME	VERSION	TYPE	DATE	TIME	SEQ #	SIZE-PRE	TEXT	(CYCLE	WORD)	PSRMODF	LOCATION
*	CONTRL		FOR SYMB	28 MAR 72	23:16:43	1		26	5	0	1	1792
*	CONTRL		RELOCATABLE	28 MAR 72	23:16:45	2	3	38				1818
	LDPORT		FOR SYMB	28 MAR 72	23:16:45	3		20	5	0	1	1859
	LDPORT		RELOCATABLE	28 MAR 72	23:16:47	4	2	15				1879
	BLDMTR		FOR SYMB	28 MAR 72	23:16:48	5		19	5	0	1	1896
	BLDMTR		RELOCATABLE	28 MAR 72	23:16:49	6	2	11				1915
	BLDKKL		FOR SYMB	28 MAR 72	23:16:50	7		26	5	0	1	1928
	BLDKKL		RELOCATABLE	28 MAR 72	23:16:52	8	3	16				1954
	RDCPRT		FOR SYMB	28 MAR 72	23:16:53	9		39	5	0	1	1973
	RDCPRT		RELOCATABLE	28 MAR 72	23:16:55	10	2	30				2012
	LDFREQ		FOR SYMB	28 MAR 72	23:16:56	11		4	5	0	1	2044
	LDFREQ		RELOCATABLE	28 MAR 72	23:16:57	12	2	3				2048
	UPPTBL		FOR SYMB	28 MAR 72	23:16:58	13		11	5	0	1	2053
	UPPTBL		RELOCATABLE	28 MAR 72	23:17:00	14	2	7				2064
	FNDLCJ		FOR SYMB	28 MAR 72	23:17:00	15		17	5	0	1	2073
	FNDLCJ		RELOCATABLE	28 MAR 72	23:17:02	16	2	11				2090
	ALOCAT		FOR SYMB	28 MAR 72	23:17:03	17		8	5	0	1	2103
	ALOCAT		RELOCATABLE	28 MAR 72	23:17:04	18	2	4				2111
	CHKSTR		FOR SYMB	28 MAR 72	23:17:04	19		3	5	0	1	2117
	CHKSTR		RELOCATABLE	28 MAR 72	23:17:06	20	2	3				2120
	FNDNET		FOR SYMB	28 MAR 72	23:17:06	21		9	5	0	1	2125
	FNDNET		RELOCATABLE	28 MAR 72	23:17:07	22	1	6				2134
	LOCMTR		FOR SYMB	28 MAR 72	23:17:08	23		4	5	0	1	2141
	LOCMTR		RELOCATABLE	28 MAR 72	23:17:09	24	1	3				2145
	LOCNAM		FOR SYMB	28 MAR 72	23:17:10	25		3	5	0	1	2149
	LOCNAM		RELOCATABLE	28 MAR 72	23:17:11	26	1	3				2152
	FNDMTR		FOR SYMB	28 MAR 72	23:17:12	27		4	5	0	1	2156
	FNDMTR		RELOCATABLE	28 MAR 72	23:17:13	28	1	3				2160
	FNDNAM		FOR SYMB	28 MAR 72	23:17:13	29		3	5	0	1	2164
	FNDNAM		RELOCATABLE	28 MAR 72	23:17:15	30	1	3				2167
	CASCDE		FOR SYMB	28 MAR 72	23:17:15	31		16	5	0	1	2171
	CASCDE		RELOCATABLE	28 MAR 72	23:17:17	32	2	9				2187
	TYPCAL		FOR SYMB	28 MAR 72	23:17:18	33		15	5	0	1	2198
	TYPCAL		RELOCATABLE	28 MAR 72	23:17:19	34	2	12				2213
	LDDT1		FOR SYMB	28 MAR 72	23:17:20	35		23	5	0	1	2227
	LDDT1		RELOCATABLE	28 MAR 72	23:17:22	36	2	17				2250
	TYPE1		FOR SYMB	28 MAR 72	23:17:23	37		13	5	0	1	2269
	TYPE1		RELOCATABLE	28 MAR 72	23:17:24	38	2	9				2282
	LDDT2		FOR SYMB	28 MAR 72	23:17:25	39		25	5	0	1	2293
	LDDT2		RELOCATABLE	28 MAR 72	23:17:27	40	2	19				2318
	TYPE2		FOR SYMB	28 MAR 72	23:17:28	41		17	5	0	1	2339
	TYPE2		RELOCATABLE	28 MAR 72	23:17:30	42	2	13				2356
	LDDT4		FOR SYMB	28 MAR 72	23:17:30	43		19	5	0	1	2371

Figure D.4. (Continued).

LDDT4	RELOCATABLE	28 MAR 72	23:17:32	44	2	13				2390
LDDT5	FOR SYMB	28 MAR 72	23:17:33	45		17	5	0	1	2405
LDDT5	RELOCATABLE	28 MAR 72	23:17:34	46	2	11				2422
LDDT7	FOR SYMB	28 MAR 72	23:17:36	47		51	5	0	1	2435
LDDT7	RELOCATABLE	28 MAR 72	23:17:38	48	2	30				2486
TYPE7	FOR SYMB	28 MAR 72	23:17:39	49		29	5	0	1	2518
TYPE7	RELOCATABLE	28 MAR 72	23:17:42	50	1	23				2546
LDDT8	FOR SYMB	28 MAR 72	23:17:42	51		22	5	0	1	2570
LDDT8	RELOCATABLE	28 MAR 72	23:17:44	52	3	20				2592
LDDT9	FOR SYMB	28 MAR 72	23:17:46	53		22	5	0	1	2615
LDDT9	RELOCATABLE	28 MAR 72	23:17:48	54	3	20				2637
LDDT11	FOR SYMB	28 MAR 72	23:17:49	55		26	5	0	1	2660
LDDT11	RELOCATABLE	28 MAR 72	23:17:51	56	3	19				2686
TYPE11	FOR SYMB	28 MAR 72	23:17:52	57		31	5	0	1	2708
TYPE11	RELOCATABLE	28 MAR 72	23:17:55	58	2	20				2739
T115BR	FOR SYMB	28 MAR 72	23:17:55	59		11	5	0	1	2770
T115BR	RELOCATABLE	28 MAR 72	23:17:57	60	2	11				2781
LDDT14	FOR SYMB	28 MAR 72	23:17:58	61		25	5	0	1	2794
LDDT14	RELOCATABLE	28 MAR 72	23:18:00	62	3	12				2819
TYPE14	FOR SYMB	28 MAR 72	23:18:00	63		3	5	0	1	2841
TYPE14	RELOCATABLE	28 MAR 72	23:18:01	64	1	2				2844
LDDT15	FOR SYMB	28 MAR 72	23:18:03	65		26	5	0	1	2847
LDDT15	RELOCATABLE	28 MAR 72	23:18:04	66	3	21				2873
TYPE15	FOR SYMB	28 MAR 72	23:18:05	67		3	5	0	1	2897
TYPE15	RELOCATABLE	28 MAR 72	23:18:06	68	1	2				2900
T14155	FOR SYMB	28 MAR 72	23:18:07	69		9	5	0	1	2903
T14155	RELOCATABLE	28 MAR 72	23:18:08	70	2	10				2912
TP1415	FOR SYMB	28 MAR 72	23:18:09	71		19	5	0	1	2924
TP1415	RELOCATABLE	28 MAR 72	23:18:11	72	2	20				2943
LDDT20	FOR SYMB	28 MAR 72	23:18:12	73		19	5	0	1	2965
LDDT20	RELOCATABLE	28 MAR 72	23:18:13	74	2	14				2984
TYPE20	FOR SYMB	28 MAR 72	23:18:14	75		13	5	0	1	3000
TYPE20	RELOCATABLE	28 MAR 72	23:18:15	76	2	10				3013
LDDT21	FOR SYMB	28 MAR 72	23:18:16	77		17	5	0	1	3025
LDDT21	RELOCATABLE	28 MAR 72	23:18:18	78	2	12				3042
TYPE21	FOR SYMB	28 MAR 72	23:18:19	79		5	5	0	1	3056
TYPE21	RELOCATABLE	28 MAR 72	23:18:19	80	1	3				3061
LDDT22	FOR SYMB	28 MAR 72	23:18:21	81		17	5	0	1	3065
LDDT22	RELOCATABLE	28 MAR 72	23:18:22	82	2	12				3082
TYPE22	FOR SYMB	28 MAR 72	23:18:22	83		5	5	0	1	3096
TYPE22	RELOCATABLE	28 MAR 72	23:18:24	84	1	4				3101
LDDT24	FOR SYMB	28 MAR 72	23:18:25	85		17	5	0	1	3106
LDDT24	RELOCATABLE	28 MAR 72	23:18:26	86	2	12				3123
TYPE24	FOR SYMB	28 MAR 72	23:18:27	87		5	5	0	1	3137
TYPE24	RELOCATABLE	28 MAR 72	23:18:28	88	1	4				3142
LDDT25	FOR SYMB	28 MAR 72	23:18:29	89		17	5	0	1	3147
LDDT25	RELOCATABLE	23 MAR 72	23:18:30	90	2	12				3164
TYPE25	FOR SYMB	28 MAR 72	23:18:31	91		5	5	0	1	3178
TYPE25	RELOCATABLE	28 MAR 72	23:18:32	92	1	4				3183
LDDT26	FOR SYMB	28 MAR 72	23:18:33	93		10	5	0	1	3188
LDDT26	RELOCATABLE	28 MAR 72	23:18:34	94	2	14				3207
TYPE26	FOR SYMB	28 MAR 72	23:18:35	95		14	5	0	1	3223
TYPE26	RELOCATABLE	28 MAR 72	23:18:37	96	2	13				3237
AIDUD	FOR SYMB	28 MAR 72	23:18:37	97		12	5	0	1	3252
AIDUD	RELOCATABLE	28 MAR 72	23:18:39	98	1	6				3264
LA2BY2	FOR SYMB	28 MAR 72	23:18:39	99		4	5	0	1	3273
LA2BY2	RELOCATABLE	28 MAR 72	23:18:40	100	1	2				3277

Figure D.4. (Continued).

LZ2BY2	FOR SYMB	28 MAR 72	23:18:40	101		4	5	0	1	3280
LZ2BY2	RELOCATABLE	28 MAR 72	23:18:42	102	1	2				3284
LZ3BY3	FOR SYMB	28 MAR 72	23:18:42	103		4	5	0	1	3287
LZ3BY3	RELOCATABLE	28 MAR 72	23:18:43	104	1	2				3291
LY2BY2	FOR SYMB	28 MAR 72	23:18:44	105		4	5	0	1	3294
LY2BY2	RELOCATABLE	28 MAR 72	23:18:45	106	1	2				3298
LY3BY3	FOR SYMB	28 MAR 72	23:18:46	107		4	5	0	1	3301
LY3BY3	RELOCATABLE	28 MAR 72	23:18:47	108	1	2				3305
LDDRIM	FOR SYMB	28 MAR 72	23:18:48	109		5	5	0	1	3308
LDDRIM	RELOCATABLE	28 MAR 72	23:18:49	110	1	4				3313
LDSB11	FOR SYMB	28 MAR 72	23:18:49	111		7	5	0	1	3318
LDSB11	RELOCATABLE	28 MAR 72	23:18:51	112	1	3				3325
LS1415	FOR SYMB	28 MAR 72	23:18:51	113		6	5	0	1	3329
LS1415	RELOCATABLE	28 MAR 72	23:18:52	114	1	3				3335
FNDTMS	FOR SYMB	28 MAR 72	23:18:53	115		9	5	0	1	3339
FNDTMS	RELOCATABLE	28 MAR 72	23:18:54	116	2	5				3348
FNDTL	FOR SYMB	28 MAR 72	23:18:55	117		13	5	0	1	3355
FNDTL	RELOCATABLE	28 MAR 72	23:18:56	118	2	9				3368
MTRMOV	FOR SYMB	28 MAR 72	23:18:57	119		4	5	0	1	3379
MTRMOV	RELOCATABLE	28 MAR 72	23:18:58	120	1	3				3383
MTRMUL	FOR SYMB	28 MAR 72	23:18:59	121		12	5	0	1	3387
MTRMUL	RELOCATABLE	28 MAR 72	23:19:00	122	1	11				3399
DLETRC	FOR SYMB	28 MAR 72	23:19:01	123		11	5	0	1	3411
DLETRC	RELOCATABLE	28 MAR 72	23:19:03	124	1	7				3422
LDIMTR	FOR SYMB	28 MAR 72	23:19:03	125		4	5	0	1	3430
LDIMTR	RELOCATABLE	28 MAR 72	23:19:04	126	1	4				3434
DECOMB	FOR SYMB	28 MAR 72	23:19:06	127		45	5	0	1	3439
DECOMB	RELOCATABLE	28 MAR 72	23:19:10	128	2	55				3484
ATOZ	FOR SYMB	28 MAR 72	23:19:10	129		10	5	0	1	3541
ATOZ	RELOCATABLE	28 MAR 72	23:19:12	130	2	9				3551
ZTOA	FOR SYMB	28 MAR 72	23:19:13	131		10	5	0	1	3562
ZTOA	RELOCATABLE	28 MAR 72	23:19:15	132	2	9				3572
ATOY	FOR SYMB	28 MAR 72	23:19:16	133		9	5	0	1	3583
ATOY	RELOCATABLE	28 MAR 72	23:19:17	134	2	11				3592
YTOA	FOR SYMB	28 MAR 72	23:19:18	135		9	5	0	1	3605
YTOA	RELOCATABLE	28 MAR 72	23:19:19	136	2	11				3614
DACMUL	FOR SYMB	28 MAR 72	23:19:20	137		3	5	0	1	3627
DACMUL	RELOCATABLE	28 MAR 72	23:19:21	138	1	2				3630
DCMMUL	FOR SYMB	28 MAR 72	23:19:22	139		3	5	0	1	3633
DCMMUL	RELOCATABLE	28 MAR 72	23:19:23	140	1	2				3636
DCMDIV	FOR SYMB	28 MAR 72	23:19:24	141		3	5	0	1	3639
DCMDIV	RELOCATABLE	28 MAR 72	23:19:25	142	1	3				3642
DCRCIP	FOR SYMB	28 MAR 72	23:19:25	143		3	5	0	1	3646
DCRCIP	RELOCATABLE	28 MAR 72	23:19:27	144	1	2				3649
DCSQRT	FOR SYMB	28 MAR 72	23:19:28	145		10	5	0	1	3652
DCSQRT	RELOCATABLE	28 MAR 72	23:19:29	146	1	9				3662
DCANG1	FOR SYMB	28 MAR 72	23:19:30	147		8	5	0	1	3672
DCANG1	RELOCATABLE	28 MAR 72	23:19:31	148	1	6				3680
DCACSH	FOR SYMB	28 MAR 72	23:19:32	149		5	5	0	1	3687
DCACSH	RELOCATABLE	28 MAR 72	23:19:33	150	1	4				3692
DSHCH	FOR SYMB	28 MAR 72	23:19:34	151		4	5	0	1	3697
DSHCH	RELOCATABLE	28 MAR 72	23:19:35	152	1	3				3701
DCSNCS	FOR SYMB	28 MAR 72	23:19:36	153		5	5	0	1	3705
DCSNCS	RELOCATABLE	28 MAR 72	23:19:37	154	1	3				3710
DCSHCH	FOR SYMB	28 MAR 72	23:19:37	155		5	5	0	1	3714
DCSHCH	RELOCATABLE	28 MAR 72	23:19:39	156	1	3				3719
PRTMTR	FOR SYMB	28 MAR 72	23:19:40	157		5	5	0	1	3723

Figure D.4. (Continued).

PRTMTR	RELOCATABLE	28 MAR 72	23:19:41	158	1	5				3728
PRTMBN	FOR SYMB	28 MAR 72	23:19:42	159		5	5	0	1	3734
PRTMBN	RELOCATABLE	28 MAR 72	23:19:43	160	1	5				3739
PRMARI	FOR SYMB	28 MAR 72	23:19:43	161		8	5	0	1	3745
PRMARI	RELOCATABLE	28 MAR 72	23:19:45	162	2	6				3753
HEAD24	FOR SYMB	28 MAR 72	23:19:45	163		6	5	0	1	3761
HEAD24	RELOCATABLE	28 MAR 72	23:19:47	164	1	6				3767
PAGE	FOR SYMB	28 MAR 72	23:19:48	165		1	5	0	1	3774
PAGE	RELOCATABLE	28 MAR 72	23:19:49	166	1	2				3775
STRLIN	FOR SYMB	28 MAR 72	23:19:49	167		2	5	0	1	3778
STRLIN	RELOCATABLE	28 MAR 72	23:19:51	168	1	2				3780
SKPLIN	FOR SYMB	28 MAR 72	23:19:51	169		2	5	0	1	3783
SKPLIN	RELOCATABLE	28 MAR 72	23:19:52	170	1	2				3785
PRPTBL	FOR SYMB	28 MAR 72	23:19:53	171		7	5	0	1	3788
PRPTBL	RELOCATABLE	28 MAR 72	23:19:54	172	1	5				3795
PRCTLG	FOR SYMB	28 MAR 72	23:19:55	173		6	5	0	1	3801
PRCTLG	RELOCATABLE	28 MAR 72	23:19:55	174	2	5				3807
UNPACK	FOR SYMB	28 MAR 72	23:19:57	175		26	5	0	1	3814
UNPACK	RELOCATABLE	28 MAR 72	23:19:59	176	1	22				3840
BLKDTA	FOR SYMB	28 MAR 72	23:20:00	177		15	5	0	1	3863
BLKDTA	RELOCATABLE	28 MAR 72	23:20:00	178	4	3				3878
TIME	FOR SYMB	28 MAR 72	23:20:01	179		5	5	0	1	3885
TIME	RELOCATABLE	28 MAR 72	23:20:02	180	1	3				3890
Z1TOZ2	FOR SYMB	28 MAR 72	23:20:03	181		8	5	0	1	3894
Z1TOZ2	RELOCATABLE	28 MAR 72	23:20:04	182	1	6				3902
DCPCT2	FOR SYMB	28 MAR 72	23:20:05	183		9	5	0	1	3909
DCPCT2	RELOCATABLE	28 MAR 72	23:20:06	184	1	7				3918
FNDKRC	FOR SYMB	28 MAR 72	23:20:07	185		26	5	0	1	3926
FNDKRC	RELOCATABLE	28 MAR 72	23:20:09	186	2	20				3952
SRCHBC	FOR SYMB	28 MAR 72	23:20:12	187		101	5	0	1	3974
SRCHBC	RELOCATABLE	28 MAR 72	23:20:16	188	4	76				4075
MINCHK	FOR SYMB	28 MAR 72	23:20:16	189		3	5	0	1	4155
MINCHK	RELOCATABLE	28 MAR 72	23:20:18	190	1	2				4158
MAXCHK	FOR SYMB	28 MAR 72	23:20:18	191		3	5	0	1	4161
MAXCHK	RELOCATABLE	28 MAR 72	23:20:19	192	1	2				4164
CMPZS	FOR SYMB	28 MAR 72	23:20:19	193		5	5	0	1	4167
CMPZS	RELOCATABLE	28 MAR 72	23:20:21	194	2	3				4172
PREPZV	FOR SYMB	28 MAR 72	23:20:22	195		16	5	0	1	4177
PREPZV	RELOCATABLE	28 MAR 72	23:20:23	196	2	18				4193
FNDFZV	FOR SYMB	28 MAR 72	23:20:24	197		7	5	0	1	4213
FNDFZV	RELOCATABLE	28 MAR 72	23:20:25	198	2	5				4220
LDZRVR	FOR SYMB	28 MAR 72	23:20:25	199		5	5	0	1	4227
LDZRVR	RELOCATABLE	28 MAR 72	23:20:27	200	2	3				4232
SRMIDB	FOR SYMB	28 MAR 72	23:20:29	201		57	5	0	1	4237
SRMIDB	RELOCATABLE	28 MAR 72	23:20:32	202	4	50				4294
LDAM2S	FOR SYMB	28 MAR 72	23:20:33	203		19	5	0	1	4348
LDAM2S	RELOCATABLE	28 MAR 72	23:20:34	204	3	15				4367
CMPGAM	FOR SYMB	28 MAR 72	23:20:36	205		16	5	0	1	4385
CMPGAM	RELOCATABLE	28 MAR 72	23:20:37	206	2	14				4401
FSRCH	FOR SYMB	28 MAR 72	23:20:41	207		142	5	0	1	4417
FSRCH	RELOCATABLE	28 MAR 72	23:20:48	208	5	123				4559
RLIMMG	FOR SYMB	28 MAR 72	23:20:48	209		10	5	0	1	4687
RLIMMG	RELOCATABLE	28 MAR 72	23:20:49	210	2	6				4697
FMFN	FOR SYMB	28 MAR 72	23:20:50	211		6	5	0	1	4705
FMFN	RELOCATABLE	28 MAR 72	23:20:51	212	2	5				4711
POLEO	FOR SYMB	28 MAR 72	23:20:52	213		14	5	0	1	4718
POLEO	RELOCATABLE	28 MAR 72	23:20:54	214	1	13				4732

Figure D.4. (Continued).

SEADUCER RUN 80002 FOR TP-22P APPENDIX D DATE 102072 PAGE 9

PRBFIT	FOR SYMB	28 MAR 72	23:20:54	215		9	5	0	1	4746
PRBFIT	RELOCATABLE	28 MAR 72	23:20:55	216	1	7				4755
FNDPRM	FOR SYMB	28 MAR 72	23:20:57	217		40	5	0	1	4763
FNDPRM	RELOCATABLE	28 MAR 72	23:21:00	218	4	29				4803
FNDFDP	FOR SYMB	28 MAR 72	23:21:00	219		8	5	0	1	4836
FNDFDP	RELOCATABLE	28 MAR 72	23:21:01	220	2	3				4844
LDBCOL	FOR SYMB	28 MAR 72	23:21:02	221		6	5	0	1	4849
LDBCOL	RELOCATABLE	28 MAR 72	23:21:03	222	2	4				4855
PRTPRM	FOR SYMB	28 MAR 72	23:21:04	223		14	5	0	1	4861
PRTPRM	RELOCATABLE	28 MAR 72	23:21:05	224	2	9				4875
CONTRL	FOR SYMB	20 OCT 72	10:25:46	225		29	5	0	1	4886
CONTRL	RELOCATABLE	20 OCT 72	10:25:52	226	3	36				4915
NEXT AVAILABLE LOCATION										4954

ASSEMBLER PROCEDURE TABLE EMPTY

COBOL PROCEDURE TABLE EMPTY

FORTRAN PROCEDURE TABLE EMPTY

ENTRY POINT TABLE

D NAME	LINK	D NAME	LINK	D NAME	LINK	D NAME	LINK	D NAME	LINK
AIDOD	98	ALOCAT	18	AIOY	134	ATOZ	130	BLDKKL	8
BLDMTR	6	CASCDE	32	CHKSTR	20	CMPGAM	206	CMPZS	194
DACMUL	138	DCACSH	150	DCANG1	148	DCMDIV	142	DCMMUL	140
DCPCT2	184	DCRCIP	144	DCSHCH	156	DCSNCS	154	DCSQRT	146
DECOMB	128	DLETRC	124	DSHCH	152	FMFN	212	FNDFDP	220
FNDFZV	198	FNDKRC	186	FNDLCJ	16	FNDMTR	28	FNDNAM	30
FNDNEI	22	FNDPRM	218	FNDTL	118	FNDIMS	116	FORMAIN$	226
FSRCH	208	HEAD24	164	LA2BY2	100	LDAM2S	204	LDBCOL	222
LDDRIM	110	LDDT1	36	LDDT11	56	LDDT14	62	LDDT15	66
LDDT2	40	LDDT20	74	LDDT21	78	LDDT22	82	LDDT24	86
LDDT25	90	LDDT26	94	LDDT4	44	LDDT5	46	LDDT7	48
LDDT8	52	LDDT9	54	LDFREQ	12	LDIMTR	126	LDPORT	4
LDSB11	112	LDZRVR	200	LOCMTR	24	LOCNAM	26	LS1415	114
LY2BY2	106	LY3BY3	108	LZ2BY2	102	LZ3BY3	104	MAXCHK	192
MINCHK	190	MTRMOV	120	MTRMUL	122	PAGE	166	POLEO	214
PRBFIT	216	PRCTLG	174	PREPZV	196	PRMARI	162	PRPTBL	172
PRTMBN	160	PRTMTR	158	PRTPRM	224	RDCPRT	10	RLIMMG	210
SKPLIN	170	SRCHBC	188	SRMIDB	202	SIRLIN	168	TIME	180
TP1415	72	TYPCAL	34	TYPE1	38	TYPE11	58	TYPE14	64
TYPE15	68	TYPE2	42	TYPE20	76	TYPE21	80	TYPE22	84
TYPE24	88	TYPE25	92	TYPE26	96	TYPE7	50	T11SBR	60
T1415S	70	UNPACK	176	UPPTBL	14	YTOA	136	ZTOA	132
Z1TOZ2	182								

Figure D.4. (Continued).

```
@MAP,XIB     SYMRUN,ABSRUN
MAP 0022-10/20-10:26 -(,U)

     1.          IN CONTRL

     2.          IN BLKUTA


ADDRESS LIMITS      001000 046223      047000 075010
STARTING ADDRESS    045441

WORDS DECIMAL       19092 IBANK        11273 DBANK


             SEGMENT MAIN              001000 046223      047000 075010

NSWTC$/FOR               1   001000 001021
NWEF$/FOR55              1   001022 001214      2   047000 047017
NFTCH$/FOR57             1   001215 001514      2   047020 047055
NCLOS$/FOR57             1   001515 001653      2   047056 047102
NBF00$/FOR                                      2   047103 051304
NBDCV$/FOR57             1   001654 002007      2   051305 051344
NFTV$/FOR                1   002010 002032
NCNVT$/FOR57             1   002033 002265      2   051345 051434
NRBLK$/FOR-NUC           1   002266 002313
NBSBL$/FOR               1   002314 002351
NUPDA$/FOR               1   002352 002405
NWBLK$/FOR57-NUC         1   002406 002530
NININ$/FOR55             1   002531 002754      2   051435 051456
NINPT$/FOR57             1   002755 003634      2   051457 051501
NOTIN$/FOR55             1   003635 004162      2   051502 051512
NFCHK$/FOR57             1   004163 004764      2   051513 051654
                                                4   051655 051726
NIOER$/FOR57             1   004765 005103      2   051727 052031
NOUT$/FOR57-UNIV         1   005104 006053      2   052032 052062
NFMT$/FOR57              1   006054 006760      2   052063 052101
NTAB$/FOR                                       2   052102 052140
ERU$/57
DLOG$/FOR54              1   006761 007101      2   052141 052245
DEXP$/FOR54              1   007102 007250      2   052246 052301
DLOG10$/FOR54            1   007251 007261      2   052302 052305
DSINCOS$/FOR57           1   007262 007423      2   052306 052364
NBKSP$/FOR50             1   007424 010115      2   052365 052415
DATAN$/FOR54             1   010116 010244      2   052416 052500
NEXP1$/FOR54             1   010245 010300      0   052501 052501
DSQRT$/FOR57             1   010301 010350      2   052502 052520
NRWND$/FOR50-NUC         1   010351 010430      2   052521 052532
NIBUF$/FOR52             1   010431 010472
```

Figure D.4. (Continued).

```
SQRT$/FOR55                 1   010473 010532     2   052533 052544
NERR$/FOR57-NUC             1   010533 011074     2   052545 052721
NSTOP$/NUC                  1   011075 011120     2   052722 052730
NOBUF$/FOR51                1   011121 011160
NIER$/FOR52                 1   011161 011243     2   052731 053060
NOSYM$/FOR57                1   011244 011476     2   053061 053066
NINTR$/NUC                  1   011477 011533     2   053067 053106
DATE-TIME/NUC-PACK          1   011534 011563     0   053107 053144
T1415S                      1   011564 012026     0   053145 053170
                            3   CS1415            2   BLANK$COMMON
                                                  4   CM1415
LY3BY3                      1   012027 012056     0   053171 053201
                            3   CY3BY3            2   BLANK$COMMON
CS1415 (COMMON BLOCK)                                 053202 053205
TP1415                      1   012057 012623     0   053206 053272
                            3   CS1415            2   BLANK$COMMON
                            5   CM1415            4   BASIC8
                                                  6   CZ3BY3
CM1415 (COMMON BLOCK)                                 053273 053324
LS1415                      1   012624 012672     0   053325 053337
                            3   CM1415            2   BLANK$COMMON
                                                  4   CEGSFP
DCSHCH                      1   012673 012752     0   053340 053356
                                                  2   BLANK$COMMON
DCACSH                      1   012753 013044     0   053357 053401
                                                  2   BLANK$COMMON
LZ3BY3                      1   013045 013074     0   053402 053412
                            3   CZ3BY3            2   BLANK$COMMON
DSHCH                       1   013075 013133     0   053413 053427
                                                  2   BLANK$COMMON
LY2BY2                      1   013134 013163     0   053430 053440
                            3   CY2BY2            2   BLANK$COMMON
COMN26 (COMMON BLOCK)                                 053441 053454
CY3BY3 (COMMON BLOCK)                                 053455 053476
TYPE26                      1   013164 013531     0   053477 053540
                            3   BASIC8            2   BLANK$COMMON
                            5   COMN26            4   CY3BY3
TYPE25                      1   013532 013613     0   053541 053560
                            3   BASIC8            2   BLANK$COMMON
TYPE24                      1   013614 013713     0   053561 053600
                            3   BASIC8            2   BLANK$COMMON
TYPE22                      1   013714 014012     0   053601 053620
                            3   BASIC8            2   BLANK$COMMON
TYPE21                      1   014013 014073     0   053621 053640
                            3   BASIC8            2   BLANK$COMMON
TYPE20                      1   014074 014327     0   053641 053726
                            3   BASIC8            2   BLANK$COMMON
                                                  4   CA2BY2
CMN15C (COMMON BLOCK)                                 053727 053730
TYPE15                      1   014330 014354     0   053731 053735
                            3   CMN15C            2   BLANK$COMMON
TYPE14                      1   014355 014401     0   053736 053742
                                                  2   BLANK$COMMON
CZ3BY3 (COMMON BLOCK)                                 053743 053764
TYPE11                      1   014402 015416     0   053765 054055
                            3   BASIC8            2   BLANK$COMMON
                            5   CZ3BY3            4   COMN11
```

Figure D.4. (Continued).

TYPE7	1	015417 016251	0	054056 054150
	3	BASICB	2	BLANK$COMMON
TYPE2	1	016252 016607	0	054151 054271
	3	BASICB	2	BLANK$COMMON
			4	CA2BY2
TYPE1	1	016610 017024	0	054272 054363
	3	BASICB	2	BLANK$COMMON
			4	CA2BY2
FNDLCJ	1	017025 017324	0	054364 054412
	3	PRTTBL	2	BLANK$COMMON
			4	CATALG
FNDNET	1	017325 017475	0	054413 054435
	3	PRTTBL	2	BLANK$COMMON
DECOND (COMMON BLOCK)				054436 054437
VALDET (COMMON BLOCK)				054440 054443
DECQ48	1	017476 021437	0	054444 054670
	3	VALDET	2	BLANK$COMMON
	5	DCMSGL	4	DECOND
DLETRC	1	021440 021637	0	054671 054730
			2	BLANK$COMMON
DCSNCS	1	021640 021722	0	054731 054747
			2	BLANK$COMMON
CY2BY2 (COMMON BLOCK)				054750 054757
ATOY	1	021723 022230	0	054760 055007
	3	CA2BY2	2	BLANK$COMMON
			4	CY2BY2
ATOZ	1	022231 022455	0	055010 055046
	3	CA2BY2	2	BLANK$COMMON
			4	CZ2BY2
MIN40V	1	022456 022524	0	055047 055064
			2	BLANK$COMMON
TYPCAL	1	022525 023027	0	055065 055111
	3	CATALG	2	BLANK$COMMON
LZ2BY2	1	023030 023057	0	055112 055122
	3	CZ2BY2	2	BLANK$COMMON
LA2BY2	1	023060 023107	0	055123 055133
	3	CA2BY2	2	BLANK$COMMON
RDCPRT	1	023110 024126	0	055134 055255
	3	CATALG	2	BLANK$COMMON
			4	CNMRDC
BLDKKL	1	024127 024540	0	055256 055342
	3	PRTTBL	2	BLANK$COMMON
	5	CNMRDC	4	CATALG
	7	CMAGIC	5	CPRTIN
			6	CFLOAT
FNDMTR	1	024541 024616	0	055343 055353
	3	CATALG	2	BLANK$COMMON
PRMARI	1	024617 024724	0	055354 055413
	3	BASICB	2	BLANK$COMMON
DCMDIV	1	024725 024772	0	055414 055426
			2	BLANK$COMMON
DCSQRT	1	024773 025221	0	055427 055463
			2	BLANK$COMMON
DCRCIP	1	025222 025254	0	055464 055472
			2	BLANK$COMMON
MINCHK	1	025255 025313	0	055473 055477
			2	BLANK$COMMON

Figure D.4. (Continued).

MAXCHK	1	025314 025352	0	055500 055504
			2	BLANK$COMMON
DCMSOL (COMMON BLOCK)				055505 056122
SRCHBC	1	025353 030056	0	056123 056456
	3	DCMSOL	2	BLANK$COMMON
	5	COMN11	4	BASIC8
	7	CERINT	6	COMNZV
	9	CMNAMP	8	CEREXT
	11	CZTVT	10	CMNDUC
	13	CSRHBC	12	CSTACK
LDZRVR	1	030057 030127	0	056457 056476
	3	LINCZV	2	BLANK$COMMON
			4	CDTAZV
FNDKRC	1	030130 030664	0	056477 056555
	3	BASIC8	2	BLANK$COMMON
			4	COMN11
FNDFZV	1	030665 030742	0	056556 056604
	3	LINCZV	2	BLANK$COMMON
			4	CDTAZV
DCANG1	1	030743 031101	0	056605 056627
			2	BLANK$COMMON
CMPGAM	1	031102 031354	0	056630 056725
	3	CMNZS	2	BLANK$COMMON
	5	GMEC1C	4	SRCHSB
	7	PRTOFF	6	PRGMTR
LDAM2S	1	031355 031702	0	056726 057011
	3	CATALG	2	BLANK$COMMON
	5	CRMRCT	4	BASIC8
	7	FLGSRH	6	SRCHSB
	9	CFLGAZ	8	PRTOFF
DACMUL	1	031703 031743	0	057012 057020
			2	BLANK$COMMON
DCMMUL	1	031744 032000	0	057021 057027
			2	BLANK$COMMON
MTRMUL	1	032001 032251	0	057030 057125
			2	BLANK$COMMON
CASCDE	1	032252 032504	0	057126 057150
	3	CATALG	2	BLANK$COMMON
			4	CFLGAZ
CZ2BY2 (COMMON BLOCK)				057151 057160
CA2BY2 (COMMON BLOCK)				057161 057170
ZTOA	1	032505 032731	0	057171 057227
	3	CA2BY2	2	BLANK$COMMON
			4	CZ2BY2
BLDMTR	1	032732 033210	0	057230 057261
	3	PRTTBL	2	BLANK$COMMON
	5	CPRI1N	4	CATALG
	7	CMAGIC	6	CNMRDC
			8	CBLD
CMPZS	1	033211 033243	0	057262 057301
	3	BASIC8	2	BLANK$COMMON
			4	CMNZS
LDFREQ	1	033244 033274	0	057302 057315
	3	BASIC8	2	BLANK$COMMON
			4	PRTOFF
LOCMTR	1	033275 033351	0	057316 057327
	3	CATALG	2	BLANK$COMMON

Figure D.4. (Continued).

```
SLADUCER RUN 80092 FOR TR-22P APPENDIX D                                                            DATE 102072        PAGE    16

PRTTBL (COMMON BLOCK)                                              065374 067510
BLANK$COMMON (COMMON BLOCK)                                        067511 074414
CONTRL                      1    045441 046223            0        074415 075010
                            3    BASICC                   2        BLANK$COMMON
                                                          4        DTATOT
BLKDTA                      3    PRTTBL                   2        BLANK$COMMON
                            5    DTASLD                   4        CATALG
                            7    PRTOFF                   6        DTATOT
                            9    CPTAND                   8        BASIC8
                           11    CBLD                    10        CFLGAZ
                           13    CPRTIN                  12        CMAGIC
                           15    CSTACK                  14        CNMPUC
                           17    CUPTBL                  16        CPRFFT
                           19    PRGMTR                  18        CSPMTR
                           21    CMNFLN                  20        CFMNPR
                                                         22        CSPHBC

SYS1*RLIB$. LEVEL 57
END OF COLLECTION - TIME 5.620 SECONDS
```

Figure D.4. (Continued).

SEADUCER RUN 80002 FOR TP-228 APPENDIX D DATE 102072 PAGE 17
WXQT ABSRUN

Figure D.4. (Continued).

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********************************************************************************
SEADUCER RUN 80002 MAY 13,1970 $ (LIKE MOD 7 RUN 70451)
MODEL 451 $
SEARCH $
CHARGE TO 16054501 TRANSMIT TECHNOLOGY

* * * * * BS  8 NETWORK TABLE

S  1B8S, 2B2B,$
S  2B8S, 1E2E,$
S  3B8S, 2Z2Z,$
S  4B8S, 1A2A, 1V2V,$
S  5B8S, 1T2A,$
S  6B8S, 1B2B, -+2A2A,$
S  7B8S, 1R2R, -+2V2V, -+2T2A,$
S  8B8S, 1Z2Z, -+2E2E, -+2R2P,$

* * * * * TS  1 NETWORK TABLE

S  1T1S, 1Z1T,$

* * * * * AS  5 NETWORK TABLE

S  1A5S, 3C3S,$
S  2A5S, 3B4S,$
S  3A5S, 4B4S, 1T1S,$
S  4A5S, 1B4S, -+1C3S,$
S  5A5S, 2B4S, -+2C3S,$

TYPE 1      RHO        AREA          ID       OD       LENGTH
A2A1$       7858.00    .821425-02    .016180  .100980  .044907
            C REAL     C IMAG        C MULT                      MASS
            5120.00    .000000       .000000                     2.89865

TYPE 1      RHO        AREA          ID       OD       LENGTH
B2B1$       7858.00    .544568-02    .058214  .101600  .004318
            C REAL     C IMAG        C MULT                      MASS
            5120.00    .000000       .000000                     .18478

TYPE 1      RHO        AREA          ID       OD       LENGTH
E2E1$       7858.00    .544568-02    .058214  .101600  .004318
            C REAL     C IMAG        C MULT                      MASS
            5120.00    .000000       .000000                     .18478

TYPE 1      RHO        AREA          ID       OD       LENGTH
V2V1$       7858.00    .617787-03    .016180  .022908  .004048
            C REAL     C IMAG        C MULT                      MASS
            5120.00    .000000       .000000                     .01965
```

Figure D.4. (Continued).

```
SEADUCER RUN 80002 FOR TP-228 APPENDIX D                                    DATE 102072        PAGE    19

TYPE 1        RHO        AREA          ID       OD       LENGTH
T2A1$         7858.00    .173586-03    .000000  .000000  .015113
              C REAL     C IMAG        C MULT                      MASS
              5120.00    .000000       .000000                     .02061

TYPE 1        RHO        AREA          ID       OD       LENGTH
T2A2$         7858.00    .601728-03    .000000  .000000  .016193
              C REAL     C IMAG        C MULT                      MASS
              5120.00    .000000       .000000                     .07656

TYPE 1        RHO        AREA          ID       OD       LENGTH
R2R1$         7858.00    .173586-03    .000000  .000000  .008500
              C REAL     C IMAG        C MULT                      MASS
              5120.00    .000000       .000000                     .01159

TYPE 1        RHO        AREA          ID       OD       LENGTH
R2R2$         7858.00    .205929-03    .000000  .000000  .257334
              C REAL     C IMAG        C MULT                      MASS
              5120.00    .000000       .000000                     .41642

TYPE 1        RHO        AREA          ID       OD       LENGTH
R2R3$         7858.00    .173586-03    .000000  .000000  .008500
              C REAL     C IMAG        C MULT                      MASS
              5120.00    .000000       .000000                     .01159

TYPE 1        RHO        AREA          ID       OD       LENGTH
Z221$         2635.00    .816851-02    .000000  .000000  .006477
              C REAL     C IMAG        C MULT                      MASS
              4950.00    .000000       .000000                     .13941

TYPE 2        RHO        A1            ID1      OD1
Z222$         2635.00    .128476-01    .000000  .000000
                         A2            ID2      OD2       LENGTH
                         .262197-01    .000000  .000000   .058293
              C REAL     C IMAG        C MULT                      MASS
              4950.00    .000000       .000000                    2.94000

TYPE 1        RHO        AREA          ID       OD       LENGTH
Z223$         2635.00    .262197-01    .000000  .000000  .016193
              C REAL     C IMAG        C MULT                      MASS
              4950.00    .000000       .000000                    1.11872

TYPE 5             REAL                 IMAG
Z1T $

     1      1   .0000000000          .0000000000

TYPE 11       RHO        AREA          ID       OD       LENGTH
C55$          7793.90    .269172-02    .083038  .101600  .021674
              C REAL     C IMAG        C MULT            N PIECES  MASS
              3545.72    .430982+01    .121550-02          10     4.54703
                   REAL                 IMAG                 MULT
```

Figure D.4. (Continued).

```
                                               PLOT LABELS    LBL1    LBL2
 * * * * * F =    3400.000000 * * * * *
   .294465+05 MAG(ZEC + ZSELF)                                              101
   .501931+07 MAG(ZIC + ZSELF)                                              102
   .895416+02 ANG(ZEC + ZSELF)                                              103
   .777489+02 ANG(ZIC + ZSELF)                                              104
   .417669+01 MAX/MIN OF MAG(VRAD/ES)                                       105
   .101010+01 MAX/MIN OF MAG(VRAD/IS)                                       106
   .262558+02 MAX-MIN OF ANG(VRAD/ES)                                       107
   .615788+00 MAX-MIN OF ANG(VRAD/IS)                                       108
   .378707-04 MIN MAG VRAD/ES               (ZR,VR)    3                    109
   .158174-03 MAX MAG VRAD/ES               (ZR,VR)    6                    110
   .262761+00 MIN MAG VRAD/IS               (ZR,VR)    9                    111
   .265414+00 MAX MAG VRAD/IS               (ZR,VR)    4                    112
  -.425216+02 MIN ANG VRAD/ES               (ZR,VR)    8                    113
  -.142658+02 MAX ANG VRAD/ES               (ZR,VR)    2                    114
   .126607+00 MIN ANG VRAD/IS               (ZR,VR)    6                    115
   .942396+00 MAX ANG VRAD/IS               (ZR,VR)    3                    116
   .125849-03 MIN POWER RAD / ES SQ         (ZR,VR)    9                    117
   .490381-03 MAX POWER RAD / ES SQ         (ZR,VR)    4                    118
   .131289+04 MIN POWER RAD / IS SQ         (ZR,VR)    6                    119
   .661180+04 MAX POWER RAD / IS SQ         (ZR,VR)    3                    120
   .375505+01 MAG( 1./A11(S2R) )                                            121
   .493008-01 ANG( 1./A11(S2R) )                                            122
   .132961+07 MAG( 1./A21(S2R) )                                            123
   .776305+02 ANG( 1./A21(S2R) )                                            124

   .196454+03 MAX MAG(E*I) AMPLIF OUT  (ZR,VR)    1                         131
      98.4967 MIN EFF (TUNED DUCER)     (ZR,VR)    6                         132
   .188168+03 MAX AMPLIF OUTPUT POWER  (ZR,VR)    1                         133
   .115797+03 AVG AMPLIF OUTPUT POWER                                       134
   .109056+04 MAX MAG EM (AMPLIF OUT)  (ZR,VR)    3                         135
   .181151+00 MAX MAG IM (AMPLIF OUT)  (ZR,VR)    7                         136
   .167755+04 MIN MAG ZM  AMPLIF LOAD  (ZR,VR)    6                         137
   .696511+04 MAX MAG ZM  AMPLIF LOAD  (ZR,VR)    3                         138
   .151435+02 MIN ANG ZM  AMPLIF LOAD  (ZR,VR)    2                         139
   .429544+02 MAX ANG ZM  AMPLIF LOAD  (ZR,VR)    8                         140
   .115797+04 TOT ARRAY AMPLF PWR OUT                                       141
      93.9674 TOT ARRAY EFF EX AMPLIF                                       142
   .111607+03 MAX IMAG E*I AMPLIF OUT  (ZR,VR)    7                         143
   .605143+02 AVG IMAG E*I AMPLIF OUT                                       144

   .127803+01 MAX CER FIELD VOLTS/MIL  (ZR,VR)    3                         161
   .135452+01 MAX CERAM POWER LOSS     (ZR,VR)    7                         162
   .211436+00 MAX MAG IC (INTO CERAM)  (ZR,VR)    1                         163
   .109056+04 MAX MAG EC (INTO CERAM)  (ZR,VR)    5                         164
   .101512+01 AVG CERAM POWER LOSS                                          165

   .624972-01 MAX MAG TAIL VELOCITY     (ZR,VR)    7                         171
   .144731+01 MAX/MIN (MAG(TAIL VEL))                                       172
   .000000    MAX TAIL OUTPUT POWER     (ZR,VR)    1                         173
   .000000    AVG TAIL OUTPUT POWER                                          174
   .186821+03 MAX RADIATED POWER        (ZR,VR)    1                         181
   .114782+03 AVG RADIATED POWER                                             182
   .114782+04 TOTAL ARRAY POWER RAD                                          183
```

Figure D.4. (Continued).

```
SEADUCER RUN 80002 FOR TP-228 APPENDIX D                                    DATE 102072        PAGE    25
      .315050+03 MAX CERAM STRESS (PSI)   (ZR,VR)    7  PIECE 7.65                  201
      .250260-04 MAX CERAM STRAIN         (ZR,VR)    7  PIECE 7.32                  202
      .155814+00 MAX CER PIECE PWR LOSS   (ZR,VR)    7  PIECE  7                    203
      .235870-01 MAX CERAM PIECE CURRENT  (ZR,VR)    1  PIECE  1                    204
         98.3575 MIN CERAM PIECE EFF      (ZR,VR)    6  PIECE  6                    205
 LAST TIME INTERVAL =    1.183 SEC             TOTAL RUN TIME =   2.241 SEC
```

Figure D.4. (Continued).

```
                                 PLOT LABELS   LBL1    LBL2
 * * * * * F =   3420.000000 * * * * *
   .314710+05 MAG(ZEC + ZSELF)                                          101
   .229025+08 MAG(ZIC + ZSELF)                                          102
   .895777+02 ANG(ZEC + ZSELF)                                          103
   .254120+00 ANG(ZIC + ZSELF)                                          104
   .398667+01 MAX/MIN OF MAG(VRAD/ES)                                   105
   .100333+01 MAX/MIN OF MAG(VRAD/IS)                                   106
   .281648+02 MAX-MIN OF ANG(VRAD/ES)                                   107
   .970130-01 MAX-MIN OF ANG(VRAD/IS)                                   108
   .374656-04 MIN MAG VRAD/ES           (ZR,VR)    3                    109
   .149363-03 MAX MAG VRAD/ES           (ZR,VR)    6                    110
   .266521+00 MIN MAG VRAD/IS           (ZR,VR)    3                    111
   .267410+00 MAX MAG VRAD/IS           (ZR,VR)    6                    112
  -.436594+02 MIN ANG VRAD/ES           (ZR,VR)    8                    113
  -.154946+02 MAX ANG VRAD/ES           (ZR,VR)    2                    114
  -.161912+00 MIN ANG VRAD/IS           (ZR,VR)    9                    115
  -.848986-01 MAX ANG VRAD/IS           (ZR,VR)    4                    116
   .121565-03 MIN POWER RAD / ES SQ     (ZR,VR)    9                    117
   .443795-03 MAX POWER RAD / ES SQ     (ZR,VR)    4                    118
   .133339+04 MIN POWER RAD / IS SQ     (ZR,VR)    6                    119
   .675022+04 MAX POWER RAD / IS SQ     (ZR,VR)    3                    120
   .373649+01 MAG( 1./A11(S2R) )                                        121
   .463325-01 ANG( 1./A11(S2R) )                                        122
   .612933+07 MAG( 1./A21(S2R) )                                        123
   .127060+00 ANG( 1./A21(S2R) )                                        124

   .196858+03 MAX MAG(E*I) AMPLIF OUT (ZR,VR)      1                    131
     98.4644 MIN EFF (TUNED DUCER)    (ZR,VR)      6                    132
   .188185+03 MAX AMPLIF OUTPUT POWER (ZR,VR)      1                    133
   .115812+03 AVG AMPLIF OUTPUT POWER                                   134
   .110236+04 MAX MAG EN (AMPLIF OUT) (ZR,VR)      3                    135
   .178724+00 MAX MAG IN (AMPLIF OUT) (ZR,VR)      1                    136
   .179033+04 MIN MAG ZM  AMPLIF LOAD (ZR,VR)      6                    137
   .711375+04 MAX MAG ZM  AMPLIF LOAD (ZR,VR)      3                    138
   .153857+02 MIN ANG ZM  AMPLIF LOAD (ZR,VR)      2                    139
   .434816+02 MAX ANG ZM  AMPLIF LOAD (ZR,VR)      8                    140
   .115812+04 TOT ARRAY AMPLF PWR OUT                                   141
     98.9751 TOT ARRAY EFF EX AMPLIF                                    142
   .113341+03 MAX IMAG E*1 AMPLIF OUT (ZR,VR)      7                    143
   .625629+02 AVG IMAG E*1 AMPLIF OUT                                   144

   .129185+01 MAX CER FIELD VOLTS/MIL (ZR,VR)      3                    161
   .137841+01 MAX CERAM POWER LOSS    (ZR,VR)      7                    162
   .210046+00 MAX MAG IC (INTO CERAM) (ZR,VR)      1                    163
   .110236+04 MAX MAG EC (INTO CERAM) (ZR,VR)      3                    164
   .102929+01 AVG CERAM POWER LOSS                                      165

   .623443-01 MAX MAG TAIL VELOCITY   (ZR,VR)      7                    171
   .144393+01 MAX/MIN (MAG(TAIL VEL))                                   172
   .000000    MAX TAIL OUTPUT POWER   (ZR,VR)      1                    173
   .000000    AVG TAIL OUTPUT POWER                                     174
   .166821+03 MAX RADIATED POWER      (ZR,VR)      1                    181
   .114782+03 AVG RADIATED POWER                                        182
   .114782+04 TOTAL ARRAY POWER RAD                                     183
```

Figure D.4. (Continued).

```
SEALUCER RUN 80002 FOR TP-22A APPENDIX D                                                          DATE 102072      PAGE   27
     .316616+03 MAX CERAM STRESS (PSI)  (ZR,VR)   7  PIECE 7.65          201
     .248700-04 MAX CERAM STRAIN        (ZR,VR)   7  PIECE 7.32          202
     .158316+00 MAX CER PIECE PWR LOSS  (ZR,VR)   7  PIECE  7            203
     .236525-01 MAX CERAM PIECE CURRENT (ZR,VR)   1  PIECE  1            204
        98.3450 MIN CERAM PIECE EFF     (ZR,VR)   6  PIECE  6            205
 LAST TIME INTERVAL =   1.123 SEC          TOTAL RUN TIME =   3.364 SEC
```

Figure D.4. (Continued).

```
                                 PLOT LABELS   LBL1    LBL2
* * * * * F =     3440.000000 * * * * *
   .334666+05 MAG(ZEC + ZSELF)                                      101
   .490865+07 MAG(ZIC + ZSELF)                                      102
   .896088+02 ANG(ZEC + ZSELF)                                      103
  -.771927+02 ANG(ZIC + ZSELF)                                      104
   .380552+01 MAX/MIN OF MAG(VRAD/ES)                               105
   .100707+01 MAX/MIN OF MAG(VRAD/IS)                               106
   .280486+02 MAX-MIN OF ANG(VRAD/ES)                               107
   .898832+00 MAX-MIN OF ANG(VRAD/IS)                               108
   .370622-04 MIN MAG VRAD/ES            (ZR,VR)   3                109
   .141041-03 MAX MAG VRAD/ES            (ZR,VR)   6                110
   .269216+00 MIN MAG VRAD/IS            (ZR,VR)   2                111
   .271121+00 MAX MAG VRAD/IS            (ZR,VR)   8                112
  -.447403+02 MIN ANG VRAD/ES            (ZR,VR)   8                113
  -.166917+02 MAX ANG VRAD/ES            (ZR,VR)   2                114
  -.120744+01 MIN ANG VRAD/IS            (ZR,VR)   3                115
  -.308610+00 MAX ANG VRAD/IS            (ZR,VR)   6                116
   .117512-03 MIN POWER RAD / ES SQ      (ZR,VR)   9                117
   .400615-03 MAX POWER RAD / ES SQ      (ZR,VR)   4                118
   .135594+04 MIN POWER RAD / IS SQ      (ZR,VR)   6                119
   .689627+04 MAX POWER RAD / IS SQ      (ZR,VR)   3                120
   .371871+01 MAG( 1./A11(S2R) )                                    121
   .473879-01 ANG( 1./A11(S2R) )                                    122
   .132875+07 MAG( 1./A21(S2R) )                                    123
  -.773287+02 ANG( 1./A21(S2R) )                                    124

   .197215+03 MAX MAG(E*I) AMPLIF OUT (ZR,VR)   1                   131
      98.4702 MIN EFF (TUNED DUCER)      (ZR,VR)   6                132
   .188203+03 MAX AMPLIF OUTPUT POWER (ZR,VR)   1                   133
   .115827+03 AVG AMPLIF OUTPUT POWER                               134
   .111453+04 MAX MAG EM (AMPLIF OUT) (ZR,VR)   1                   135
   .176948+00 MAX MAG IM (AMPLIF OUT) (ZR,VR)   1                   136
   .191194+04 MIN MAG ZM  AMPLIF LOAD (ZR,VR)   6                   137
   .726856+04 MAX MAG ZM  AMPLIF LOAD (ZR,VR)   3                   138
   .155772+02 MIN ANG ZM  AMPLIF LOAD (ZR,VR)   2                   139
   .439334+02 MAX ANG ZM  AMPLIF LOAD (ZR,VR)   8                   140
   .115827+04 TOT ARRAY AMPLF PWR OUT                               141
      98.9618 TOT ARRAY EFF EX AMPLIF                               142
   .114802+03 MAX IMAG E*I AMPLIF OUT (ZR,VR)   7                   143
   .644746+02 AVG IMAG E*I AMPLIF OUT                               144

   .130612+01 MAX CER FIELD VOLTS/MIL (ZR,VR)   1                   161
   .140329+01 MAX CERAM POWER LOSS       (ZR,VR)   7                162
   .208804+00 MAX MAG IC (INTO CERAM) (ZR,VR)   1                   163
   .111453+04 MAX MAG EC (INTO CERAM) (ZR,VR)   1                   164
   .104426+01 AVG CERAM POWER LOSS                                  165

   .621922-01 MAX MAG TAIL VELOCITY      (ZR,VR)   7                171
   .144058+01 MAX/MIN (MAG(TAIL VEL))                               172
   .000000    MAX TAIL OUTPUT POWER      (ZR,VR)   1                173
   .000000    AVG TAIL OUTPUT POWER                                 174
   .186821+03 MAX RADIATED POWER         (ZR,VR)   1                181
   .114782+03 AVG RADIATED POWER                                    182
   .114782+04 TOTAL ARRAY POWER RAD                                 183
```

Figure D.4. (Continued).

```
SEADUCER RUN E0002 FOR TR-22P APPENDIX D                                                              DATE 102072        PAGE    29
   .318177+03 MAX CERAM STRESS (PSI)   (ZR,VR)    7  PIECE 7.65                 201
   .247160-04 MAX CERAM STRAIN         (ZR,VR)    7  PIECE 7.32                 202
   .160918+00 MAX CER PIECE PWR LOSS   (ZR,VR)    7  PIECE  7                   203
   .237358-01 MAX CERAM PIECE CURRENT  (ZR,VR)    1  PIECE  1                   204
      98.3506 MIN CERAM PIECE EFF      (ZR,VR)    6  PIECE  6                   205
 LAST TIME INTERVAL =    1.004 SEC           TOTAL RUN TIME =   4.368 SEC
```

Figure D.4. (Continued).

```
                                    PLOT LABELS    LBL1     LBL2
* * * * * F =    3460.000000 * * * * *
  .354350+05 MAG(ZEC + ZSELF)                                          101
  .246908+07 MAG(ZIC + ZSELF)                                          102
  .896359+02 ANG(ZEC + ZSELF)                                          103
 -.833680+02 ANG(ZIC + ZSELF)                                          104
  .363539+01 MAX/MIN OF MAG(VRAD/ES)                                   105
  .101327+01 MAX/MIN OF MAG(VRAD/IS)                                   106
  .292923+02 MAX-MIN OF ANG(VRAD/ES)                                   107
  .178603+01 MAX-MIN OF ANG(VRAD/IS)                                   108
  .366611-04 MIN MAG VRAD/ES            (ZR,VR)    3                   109
  .133277-03 MAX MAG VRAD/ES            (ZR,VR)    6                   110
  .271896+00 MIN MAG VRAD/IS            (ZR,VR)    4                   111
  .275505+00 MAX MAG VRAD/IS            (ZR,VR)    8                   112
 -.471503+02 MIN ANG VRAD/ES            (ZR,VR)    6                   113
 -.178580+02 MAX ANG VRAD/ES            (ZR,VR)    2                   114
 -.231801+01 MIN ANG VRAD/IS            (ZR,VR)    3                   115
 -.531985+00 MAX ANG VRAD/IS            (ZR,VR)    6                   116
  .113623-03 MIN POWER RAD / ES SG      (ZR,VR)    9                   117
  .361356-03 MAX POWER RAD / ES SG      (ZR,VR)    4                   118
  .138064+04 MIN POWER RAD / IS SG      (ZR,VR)    6                   119
  .705013+04 MAX POWER RAD / IS SG      (ZR,VR)    3                   120
  .370166+01 MAG( 1./A11(S2R) )                                        121
  .464657-01 ANG( 1./A11(S2R) )                                        122
  .676524+06 MAG( 1./A21(S2R) )                                        123
 -.835132+02 ANG( 1./A21(S2R) )                                        124

  .197519+03 MAX MAG(E*I) AMPLIF OUT (ZR,VR)    1                      131
     98.4541 MIN EFF (TUNED DUCER)      (ZR,VR)    6                   132
  .188222+03 MAX AMPLIF OUTPUT POWER (ZR,VR)    1                      133
  .115842+03 AVG AMPLIF OUTPUT POWER                                   134
  .112792+04 MAX MAG EM (AMPLIF OUT) (ZR,VR)    1                      135
  .175289+00 MAX MAG IM (AMPLIF OUT) (ZR,VR)    4                      136
  .204165+04 MIN MAG ZM  AMPLIF LOAD (ZR,VR)    6                      137
  .742959+04 MAX MAG ZM  AMPLIF LOAD (ZR,VR)    3                      138
  .157173+02 MIN ANG ZM  AMPLIF LOAD (ZR,VR)    2                      139
  .466163+02 MAX ANG ZM  AMPLIF LOAD (ZR,VR)    6                      140
  .115842+04 TOT ARRAY AMPLF PWR OUT                                   141
     98.9476 TOT ARRAY EFF EX AMPLIF                                   142
  .115985+03 MAX IMAG E*I AMPLIF OUT (ZR,VR)    7                      143
  .661851+02 AVG IMAG E*I AMPLIF OUT                                   144

  .132181+01 MAX CER FIELD VOLTS/MIL (ZR,VR)    1                      161
  .142916+01 MAX CERAM POWER LOSS       (ZR,VR)    7                   162
  .207714+00 MAX MAG IC (INTO CERAM) (ZR,VR)    1                      163
  .112792+04 MAX MAG EC (INTO CERAM) (ZR,VR)    1                      164
  .106000+01 AVG CERAM POWER LOSS                                      165

  .620410-01 MAX MAG TAIL VELOCITY      (ZR,VR)    7                   171
  .143727+01 MAX/MIN (MAG(TAIL VEL))                                   172
  .000000    MAX TAIL OUTPUT POWER      (ZR,VR)    1                   173
  .000000    AVG.TAIL OUTPUT POWER                                     174
  .186821+03 MAX RADIATED POWER         (ZR,VR)    1                   181
  .114782+03 AVG RADIATED POWER                                        182
  .114782+04 TOTAL ARRAY POWER RAD                                     183
```

Figure D.4. (Continued).

```
SEADUCER RUN 80002 FOR TP-228 APPENDIX D                                                DATE 102072        PAGE   71
    .319733+03 MAX CERAM STRESS (PSI)   (ZR,VR)    7  PIECE 7.64            201
    .245641-04 MAX CERAM STRAIN         (ZR,VR)    7  PIECE 7.33            202
    .163619+00 MAX CER PIECE PWR LOSS   (ZR,VR)    7  PIECE  7              203
    .238368-01 MAX CERAM PIECE CURRENT  (ZR,VR)    1  PIECE  1              204
       98.3117 MIN CERAM PIECE EFF      (ZR,VR)    6  PIECE  7              205
 LAST TIME INTERVAL =    1.062 SEC          TOTAL RUN TIME =    5.430 SEC
```

Figure D.4. (Continued).

```
                         PLOT LABELS   LBL1    LBL2
 * * * * * F =    3460.000000 * * * * *
     .373773+05 MAG(ZEC + ZSELF)                                        101
     .163093+07 MAG(ZIC + ZSELF)                                        102
     .896596+02 ANG(ZEC + ZSELF)                                        103
    -.854613+02 ANG(ZIC + ZSELF)                                        104
     .348479+01 MAX/MIN OF MAG(VRAD/ES)                                 105
     .102085+01 MAX/MIN OF MAG(VRAD/IS)                                 106
     .307498+02 MAX-MIN OF ANG(VRAD/ES)                                 107
     .269472+01 MAX-MIN OF ANG(VRAD/IS)                                 108
     .362630-04 MIN MAG VRAD/ES          (ZR,VR)   3                    109
     .126369-03 MAX MAG VRAD/ES          (ZR,VR)   4                    110
     .274439+00 MIN MAG VRAD/IS          (ZR,VR)   4                    111
     .280161+00 MAX MAG VRAD/IS          (ZR,VR)   8                    112
    -.497440+02 MIN ANG VRAD/ES          (ZR,VR)   6                    113
    -.189941+02 MAX ANG VRAD/ES          (ZR,VR)   2                    114
    -.345449+01 MIN ANG VRAD/IS          (ZR,VR)   3                    115
    -.759779+00 MAX ANG VRAD/IS          (ZR,VR)   6                    116
     .109910-03 MIN POWER RAD / ES SQ    (ZR,VR)   9                    117
     .326116-03 MAX POWER RAD / ES SQ    (ZR,VR)   4                    118
     .140761+04 MIN POWER RAD / IS SQ    (ZR,VR)   6                    119
     .721199+04 MAX POWER RAD / IS SQ    (ZR,VR)   3                    120
     .368531+01 MAG( 1./A11(S2R) )                                      121
     .455650-01 ANG( 1./A11(S2R) )                                      122
     .452656+06 MAG( 1./A21(S2R) )                                      123
    -.856161+02 ANG( 1./A21(S2R) )                                      124

     .197768+03 MAX MAG(E*I) AMPLIF OUT (ZR,VR)    1                    131
        98.4361 MIN EFF (TUNED DUCER)   (ZR,VR)    6                    132
     .188241+03 MAX AMPLIF OUTPUT POWER (ZR,VR)    1                    133
     .115859+03 AVG AMPLIF OUTPUT POWER                                 134
     .114160+04 MAX MAG EM (AMPLIF OUT) (ZR,VR)    1                    135
     .173664+00 MAX MAG IM (AMPLIF OUT) (ZR,VR)    4                    136
     .217173+04 MIN MAG ZM  AMPLIF LOAD (ZR,VR)    4                    137
     .759689+04 MAX MAG ZM  AMPLIF LOAD (ZR,VR)    3                    138
     .158051+02 MIN ANG ZM  AMPLIF LOAD (ZR,VR)    2                    139
     .489842+02 MAX ANG ZM  AMPLIF LOAD (ZR,VR)    6                    140
     .115859+04 TOT ARRAY AMPLF PWR OUT                                 141
        98.9325 TOT ARRAY EFF EX AMPLIF                                 142
     .116887+03 MAX IMAG E*I AMPLIF OUT (ZR,VR)    7                    143
     .677104+02 AVG IMAG E*I AMPLIF OUT                                 144

     .133784+01 MAX CER FIELD VOLTS/MIL (ZR,VR)    1                    161
     .145600+01 MAX CERAM POWER LOSS    (ZR,VR)    7                    162
     .206781+00 MAX MAG IC (INTO CERAM) (ZR,VR)    1                    163
     .114160+04 MAX MAG EC (INTO CERAM) (ZR,VR)    1                    164
     .107653+01 AVG CERAM POWER LOSS                                    165

     .618905-01 MAX MAG TAIL VELOCITY   (ZR,VR)    7                    171
     .143399+01 MAX/MIN (MAG(TAIL VEL))                                 172
     .000000    MAX TAIL OUTPUT POWER   (ZR,VR)    1                    173
     .000000    AVG TAIL OUTPUT POWER                                   174
     .186821+03 MAX RADIATED POWER      (ZR,VR)    1                    181
     .114782+03 AVG RADIATED POWER                                      182
     .114782+04 TOTAL ARRAY POWER RAD                                   183
```

Figure D.4. (Continued).

```
SEADUCER RUN 80002 FOR TP-228 APPENDIX D                                                      DATE 102072        PAGE    33

     .321285+03 MAX CERAM STRESS (PSI)  (ZR,VR)   7  PIECE 7.64          201
     .244143-04 MAX CERAM STRAIN        (ZR,VR)   7  PIECE 7.33          202
     .166419+00 MAX CER PIECE PWR LOSS  (ZR,VR)   7  PIECE  7            203
     .239555-01 MAX CERAM PIECE CURRENT (ZR,VR)   1  PIECE  1            204
        98.2906 MIN CERAM PIECE EFF     (ZR,VR)   6  PIECE  7            205
  LAST TIME INTERVAL =     .972 SEC           TOTAL RUN TIME =   6.402 SEC
```

Figure D.4. (Continued).

```
                                  PLOT LABELS   LBL1    LBL2
 * * * * * F =   3500.000000 * * * * *
   .392949+05 MAG(ZEC + ZSELF)                                   101
   .120848+07 MAG(ZIC + ZSELF)                                   102
   .896807+02 ANG(ZEC + ZSELF)                                   103
  -.865078+02 ANG(ZIC + ZSELF)                                   104
   .334936+01 MAX/MIN OF MAG(VRAD/ES)                            105
   .102856+01 MAX/MIN OF MAG(VRAD/IS)                            106
   .319564+02 MAX-MIN OF ANG(VRAD/ES)                            107
   .362611+01 MAX-MIN OF ANG(VRAD/IS)                            108
   .358664-04 MIN MAG VRAD/ES           (ZR,VR)   3              109
   .120136-03 MAX MAG VRAD/ES           (ZR,VR)   4              110
   .277186+00 MIN MAG VRAD/IS           (ZR,VR)   4              111
   .265103+00 MAX MAG VRAD/IS           (ZR,VR)   8              112
  -.520593+02 MIN ANG VRAD/ES           (ZR,VR)   6              113
  -.201008+02 MAX ANG VRAD/ES           (ZR,VR)   2              114
  -.461856+01 MIN ANG VRAD/IS           (ZR,VR)   3              115
  -.992451+00 MAX ANG VRAD/IS           (ZR,VR)   6              116
   .106366-03 MIN POWER RAD / ES SQ     (ZR,VR)   9              117
   .294740-03 MAX POWER RAD / ES SQ     (ZR,VR)   4              118
   .143700+04 MIN POWER RAD / IS SQ     (ZR,VR)   6              119
   .738202+04 MAX POWER RAD / IS SQ     (ZR,VR)   3              120
   .366965+01 MAG( 1./A11(S2R) )                                 121
   .446846-01 ANG( 1./A11(S2R) )                                 122
   .340003+06 MAG( 1./A21(S2R) )                                 123
  -.866724+02 ANG( 1./A21(S2R) )                                 124

   .197958+03 MAX MAG(E*I) AMPLIF OUT (ZR,VR)     1              131
     98.4161 MIN EFF (TUNED DUCER)     (ZR,VR)    6              132
   .168262+03 MAX AMPLIF OUTPUT POWER  (ZR,VR)    1              133
   .115876+03 AVG AMPLIF OUTPUT POWER                            134
   .115555+04 MAX MAG Em (AMPLIF OUT)  (ZR,VR)    1              135
   .171943+00 MAX MAG Im (AMPLIF OUT)  (ZR,VR)    4              136
   .230726+04 MIN MAG Zm  AMPLIF LOAD  (ZR,VR)    4              137
   .777048+04 MAX MAG Zm  AMPLIF LOAD  (ZR,VR)    3              138
   .158398+02 MIN ANG Zm  AMPLIF LOAD  (ZR,VR)    2              139
   .510668+02 MAX ANG Zm  AMPLIF LOAD  (ZR,VR)    6              140
   .115876+04 TOT ARRAY AMPLF PWR OUT                            141
     98.9164 TOT ARRAY EFF EX AMPLIF                             142
   .117505+03 MAX IMAG E*I AMPLIF OUT  (ZR,VR)    7              143
   .690464+02 AVG IMAG E*I AMPLIF OUT                            144

   .135419+01 MAX CER FIELD VOLTS/MIL  (ZR,VR)    1              161
   .148382+01 MAX CERAM POWER LOSS     (ZR,VR)    7              162
   .206009+00 MAX MAG IC (INTO CERAM)  (ZR,VR)    1              163
   .115555+04 MAX MAG EC (INTO CERAM)  (ZR,VR)    1              164
   .109382+01 AVG CERAM POWER LOSS                               165

   .617408-01 MAX MAG TAIL VELOCITY    (ZR,VR)    7              171
   .143075+01 MAX/MIN (MAG(TAIL VEL))                            172
   .000000    MAX TAIL OUTPUT POWER    (ZR,VR)    1              173
   .000000    AVG TAIL OUTPUT POWER                              174
   .186821+03 MAX RADIATED POWER       (ZR,VR)    1              181
   .114782+03 AVG RADIATED POWER                                 182
   .114782+04 TOTAL ARRAY POWER RAD                              183
```

Figure D.4. (Continued).

```
SEADUCER RUN 80002 FOR TP-228 APPENDIX D                                                   DATE 102072        PAGE    35
     .322831+03 MAX CERAM STRESS (PSI)   (ZR,VR)    7  PIECE 7.64              201
     .242665-04 MAX CERAM STRAIN         (ZR,VR)    7  PIECE 7.33              202
     .169318+00 MAX CER PIECE PWR LOSS   (ZR,VR)    7  PIECE  7                203
     .240919-01 MAX CERAM PIECE CURRENT  (ZR,VR)    1  PIECE  1                204
        98.2677 MIN CERAM PIECE EFF      (ZR,VR)    6  PIECE  7                205
 LAST TIME INTERVAL =    1.004 SEC              TOTAL RUN TIME =    7.406 SEC
```

Figure D.4. (Continued).

```
SEADUCER RUN 80002 FOR TP-220 APPENDIX D                                          DATE 102072       PAGE   [illegible]6

  BAND WIDTH  MAG ZM SPREAD  ANG ZM SPREAD
   .000000       .380167+01    .2[illegible]5562+02
   .400000+02    .414984+01    .312326+02
   .800000+02    .452556+01    .336407+02
 LAST TIME INTERVAL =    .030 SEC           TOTAL RUN TIME =   7.435 SEC
```

Figure D.4. (Continued)

* * * * * COMMON PRT TBL * * * * *

N	NET SP	I SIGN C	D	J PORT	N PORTS	NET NA.	NUM APO	NUM NPO	N AHEAD	N BACK	LC J ROW
1	S	1	1	1	8	JS	1	-1	3	0	1
2	S	1	1	2	2	BJ	1	2	4	13	401
3	S	1	1	2	8	BS	2	-2	5	1	2
4	S	1	1	1	2	EE	2	3	21	2	439
5	S	1	1	3	8	BS	3	-3	7	3	3
6	S	1	1	2	2	ZZ	3	6	6	20	665
7	S	1	1	4	8	BS	4	-4	10	5	4
8	S	1	1	1	2	AA	4	7	14	6	361
9	S	1	1	1	2	VV	4	9	17	14	478
10	S	1	1	5	8	BS	5	-5	12	7	5
11	S	1	1	1	2	TA	5	11	18	17	517
12	S	1	1	6	8	BS	6	-6	15	10	6
13	S	1	1	1	2	BJ	6	1	2	0	400
14	S	-1	1	2	2	AA	6	8	9	8	362
15	S	1	1	7	8	BS	7	-7	19	12	7
16	S	1	1	1	2	RR	7	13	22	18	579
17	S	-1	1	2	2	VV	7	10	11	9	479
18	S	-1	1	2	2	TA	7	12	16	11	518
19	S	1	1	6	8	BS	8	-8	23	15	8
20	S	1	1	1	2	ZZ	8	5	6	21	664
21	S	-1	1	2	2	EE	8	4	20	4	440
22	S	-1	1	2	2	RR	8	14	0	16	580
23	S	1	1	1	1	TS	1	-1	25	19	257
24	S	1	1	1	1	ZT	1	1	0	0	750
25	S	1	1	1	5	AS	1	-1	27	23	261
26	S	1	1	3	3	CS	1	3	33	37	756
27	S	1	1	2	5	AS	2	-2	29	25	262
28	S	1	1	3	4	BS	2	6	30	36	881
29	S	1	1	3	5	AS	3	-3	32	27	263
30	S	1	1	4	4	BS	3	7	31	28	882
31	S	1	1	1	1	TS	3	8	0	30	257
32	S	1	1	4	5	AS	4	-4	35	29	264
33	S	1	1	1	4	BS	4	4	36	26	879
34	S	-1	1	1	3	CS	4	1	37	0	754
35	S	1	1	5	5	AS	5	-5	0	32	265
36	S	1	1	2	4	BS	5	5	28	33	880
37	S	-1	1	2	3	CS	5	2	26	34	755

Figure D.4. (Continued).

SEADUCER RUN 80002 FOR TP-228 APPENDIX D   DATE 102072   PAGE 38

* * * * * COMMON CATALG * * * * *

I	NAME	MTR SIZ	I PC	N PC LOT	I TYPE	N DT STR	LOC
1	BS	8	0	0	0	0	1
2	TS	1	0	0	0	0	257
3	AS	5	0	0	0	0	261
4	AA	2	0	1	0	0	361
5	AA	2	1	1	1	7	377
6	BB	2	0	1	0	0	400
7	BB	2	1	1	1	7	416
8	EE	2	0	1	0	0	439
9	EE	2	1	1	1	7	455
10	VV	2	0	1	0	0	478
11	VV	2	1	1	1	7	494
12	TA	2	0	2	0	0	517
13	TA	2	1	2	1	7	533
14	TA	2	2	2	1	7	556
15	RR	2	0	3	0	0	579
16	RR	2	1	3	1	7	595
17	RR	2	2	3	1	7	618
18	RR	2	3	3	1	7	641
19	ZZ	2	0	3	0	0	664
20	ZZ	2	1	3	1	7	680
21	ZZ	2	2	3	2	8	703
22	ZZ	2	3	3	1	7	727
23	ZT	1	0	0	5	0	750
24	CS	3	0	0	11	33	754
25	FS	2	0	0	0	0	823
26	DS	2	0	0	0	0	831
27	SS	2	0	0	0	0	839
28	GS	2	0	0	0	0	847
29	ES	2	0	0	0	0	855
30	HS	2	0	0	0	0	863
31	MS	2	0	0	0	0	871
32	BS	4	0	0	0	0	879
33	BS	0	0	0	0	0	943
34	BS	0	0	0	0	0	1007
35	AS	2	0	0	0	0	1071
36	AS	0	0	0	0	0	1087
37	AS	0	0	0	0	0	1123
38	BC	4	0	0	0	0	1147
39	ZC	3	0	0	0	0	1211
40	RC	3	0	0	0	0	1229

TOTAL DATA CELLS USED IN MASTER STORAGE   1246

Figure D.4. (Continued).

```
SEADUCER RUN 80002 FOR TP-228 APPENDIX D                                          DATE 102072     PAGE  39
 LAST TIME INTERVAL =    .412 SEC          TOTAL RUN TIME =   7.848 SEC

@BRKPT   PRINTS


    RUNID:  M80002    ACCOUNT: 1E0170010000    PROJECT: LME010314522
      LOAD R80002 9/7 PRFILE       -1 M80002
     M80002*MSG: SD 2119
     BREAKPOINT IN THIS RUN
 *M80002 R80002=3738 P80002=525
      LOAD 279     9/0 8           -1 M80002
      SERVICE      9/0
      LOAD P80002 9/2 14           -1 M80002
    TIME: 00:00:17.135    IN: 147     OUT: 0        PAGES:   47
    WDS XFRD(E2): 5364    I/O REFS: 2197    CORE SEC: 957
    INITIATION  TIME:   10:20:27-OCT 20,1972      VERSION:  2E.70.158 10
    TERMINATION TIME:   10:27:49-OCT 20,1972
     BREAKPOINT IN THIS RUN
```

Figure D.4. (Continued)

Figure D.5.

Computer-generated Plots from Search Procedure.

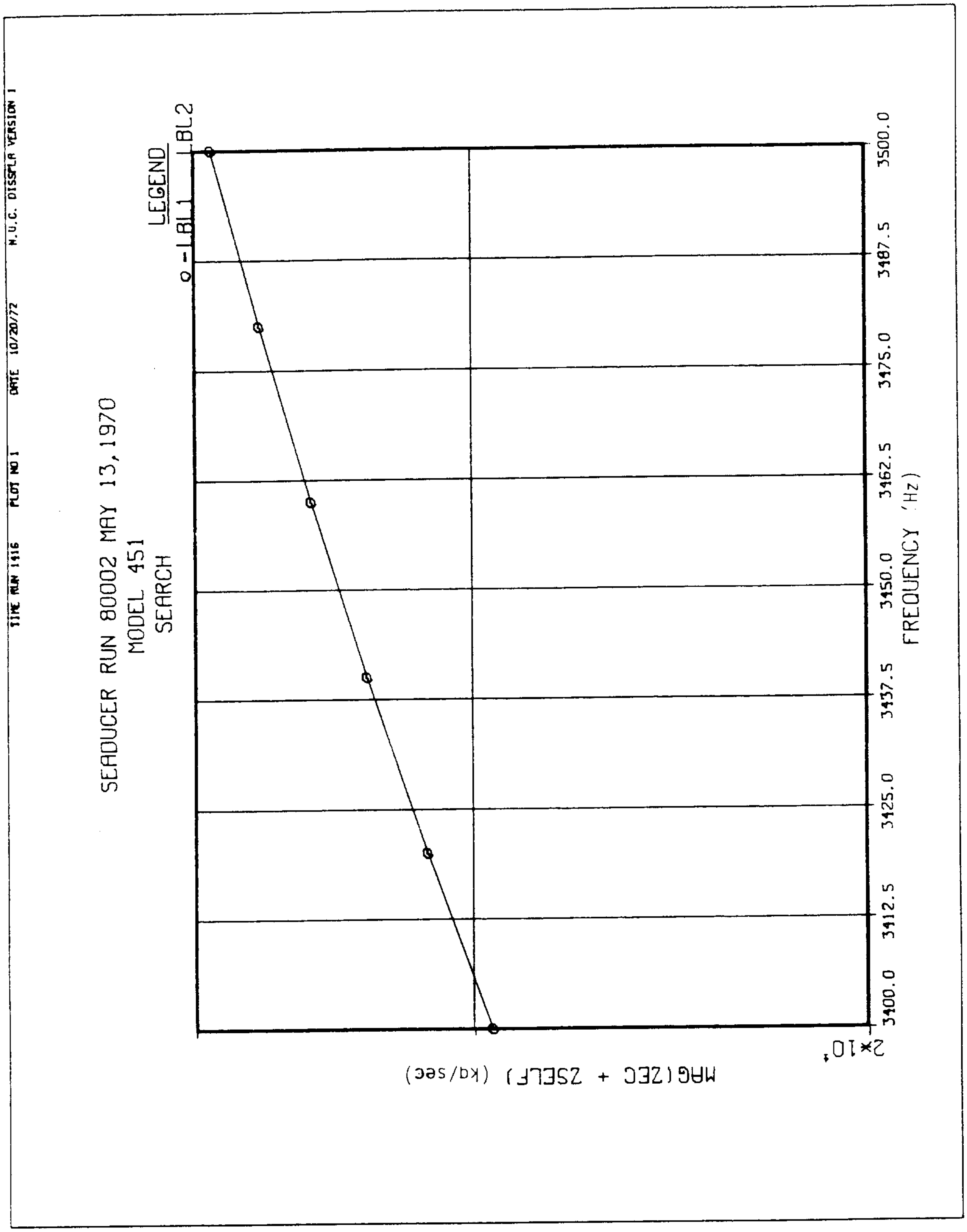

Figure D.5. (Continued).

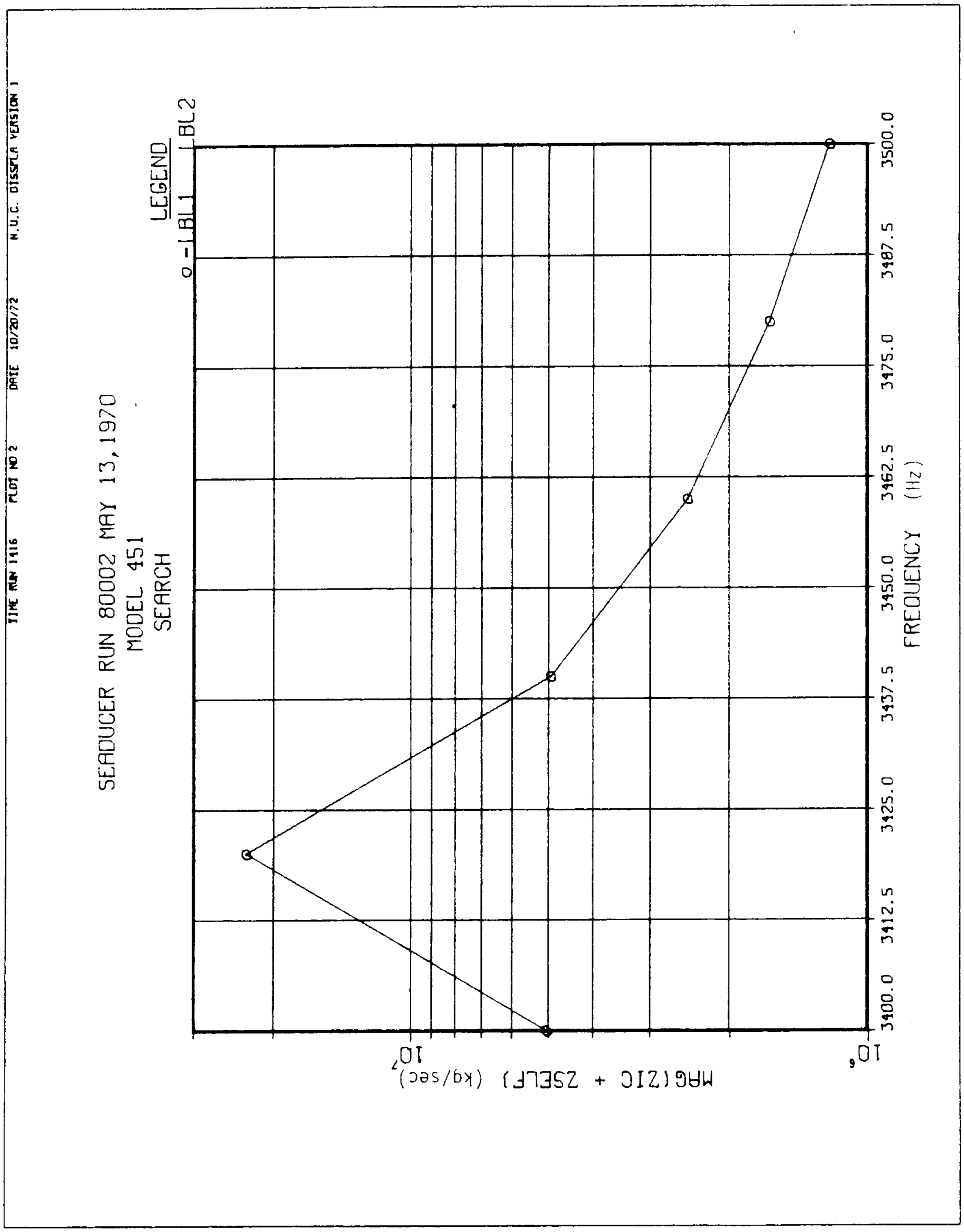

Figure D.5. (Continued).

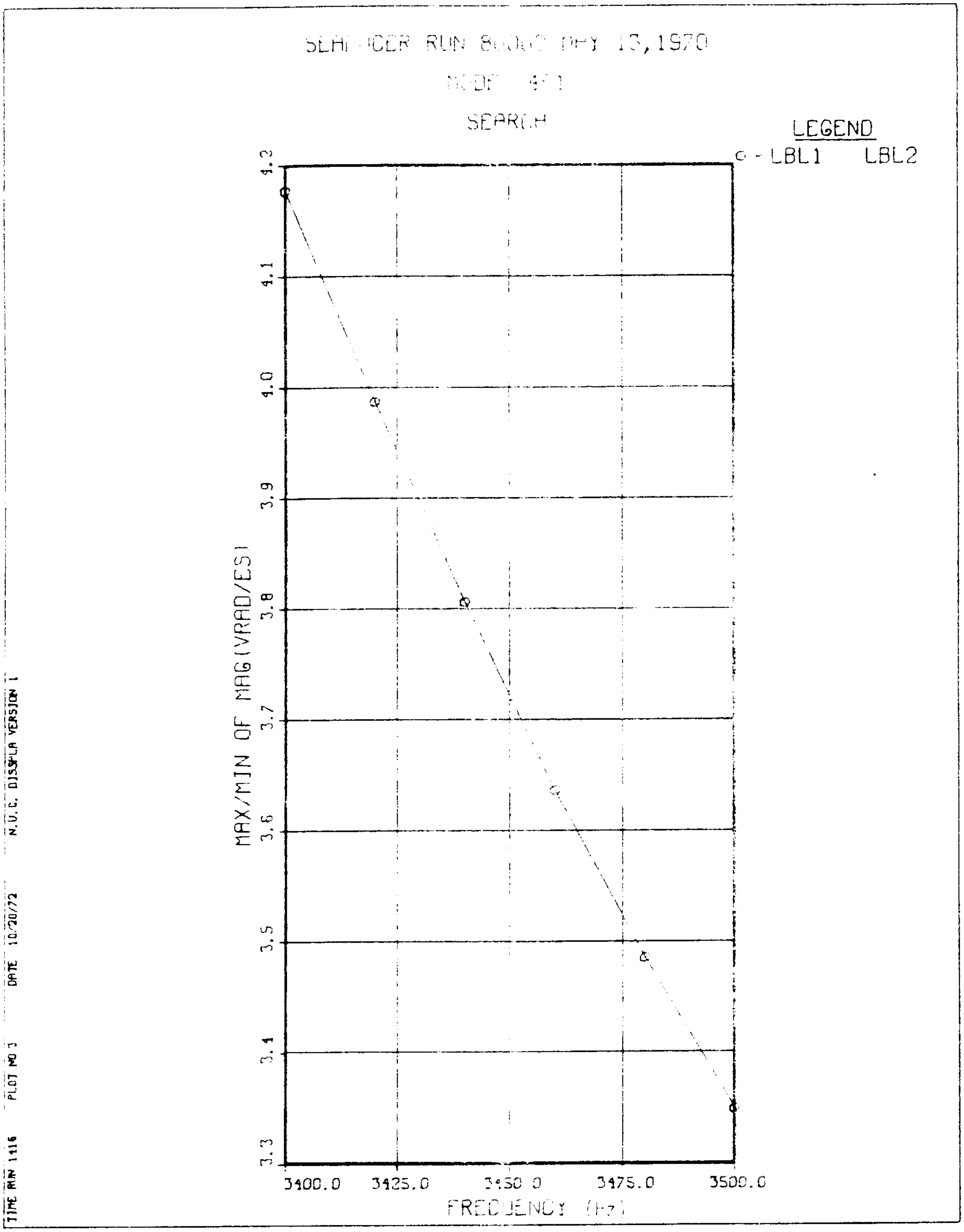

Figure D.5. (Continued).

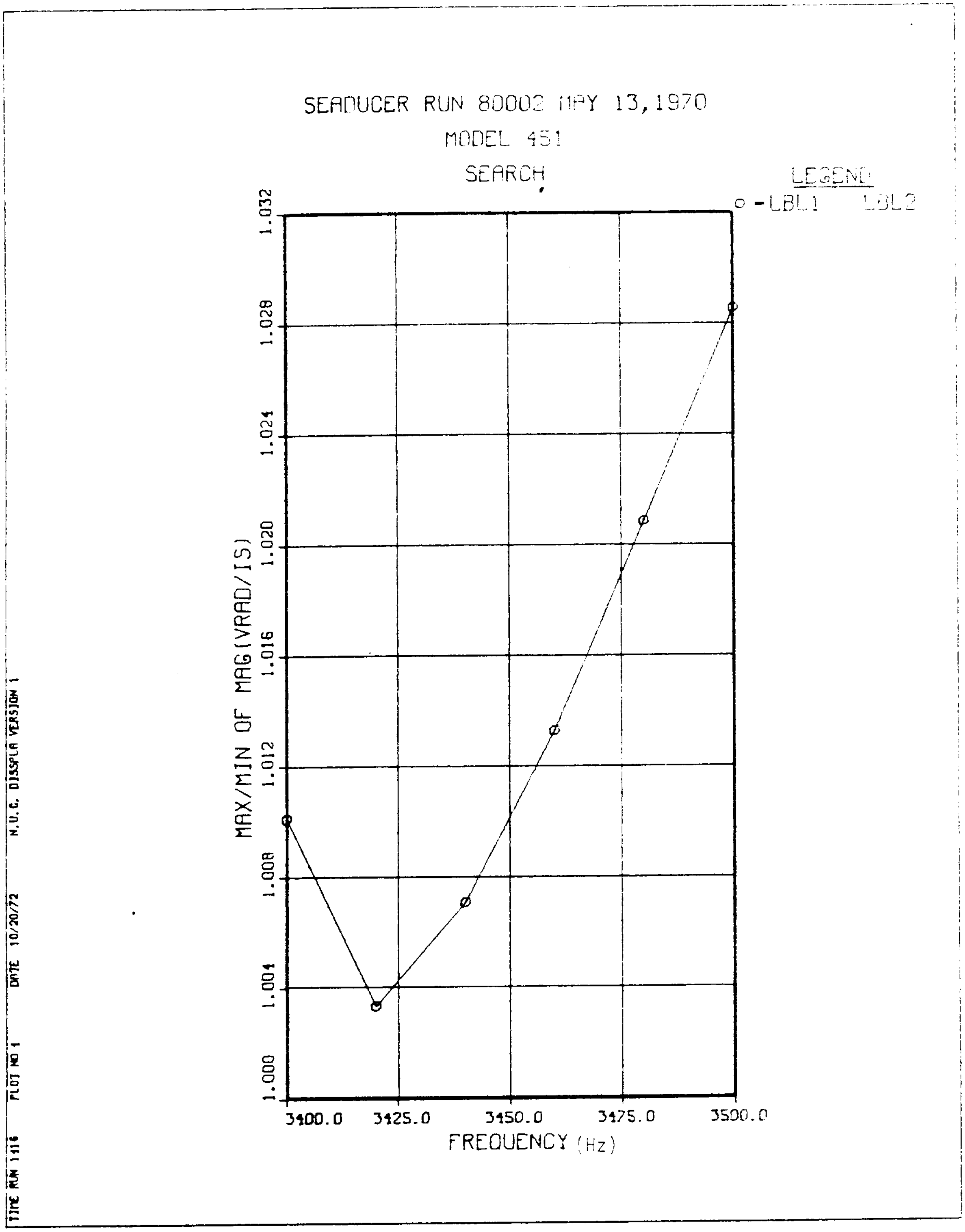

Figure D.5. (Continued).

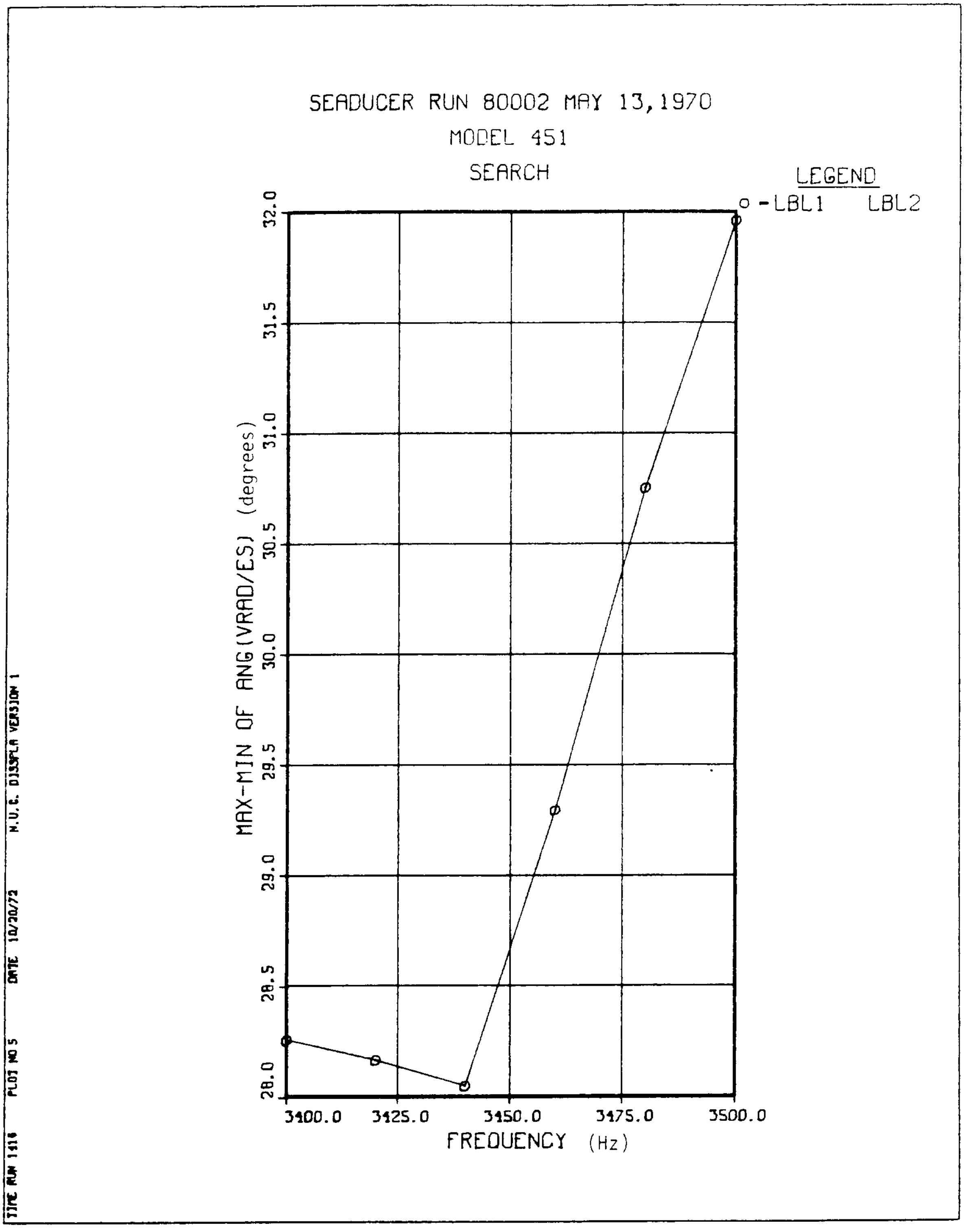

Figure D.5. (Continued).

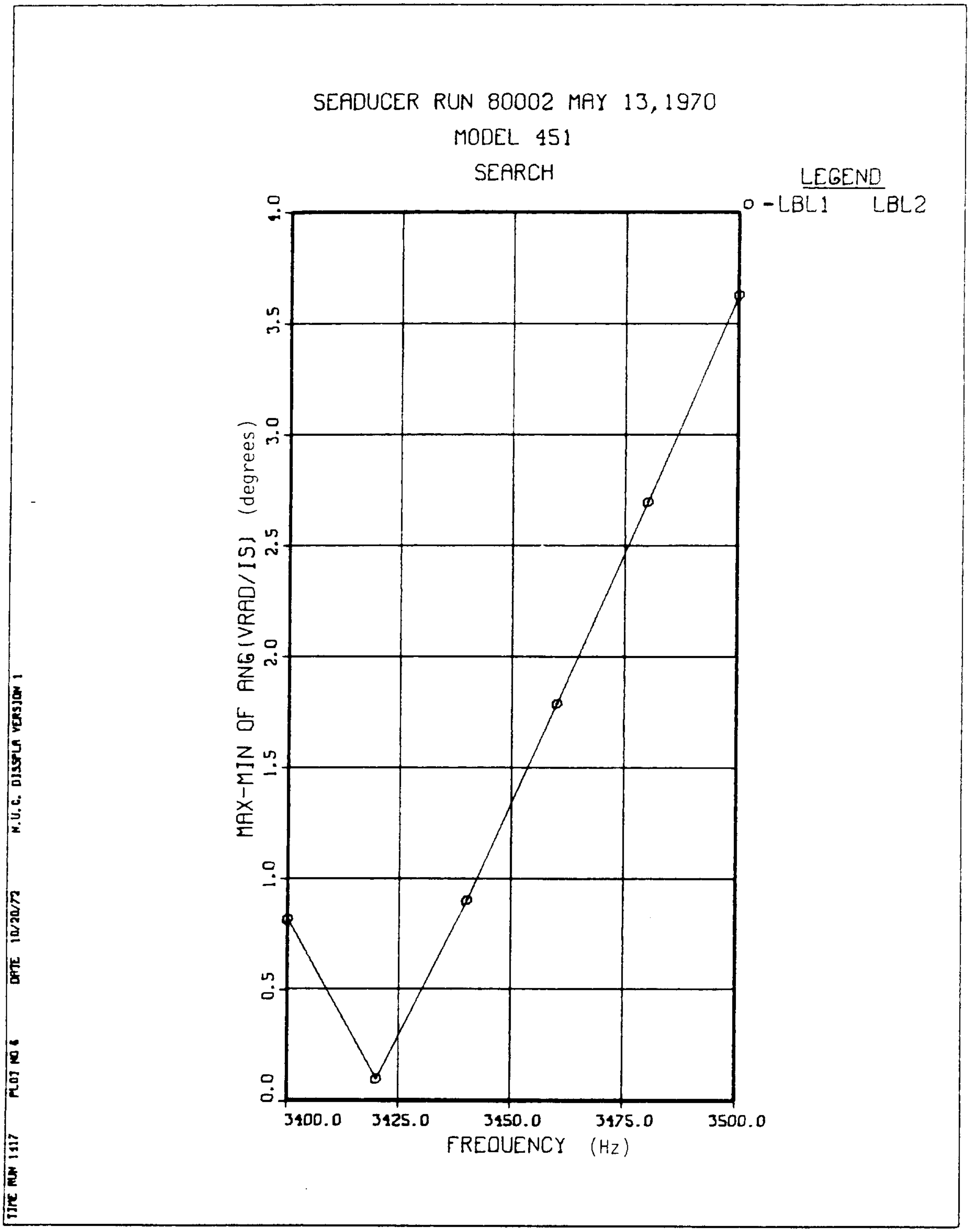

Figure D.5. (Continued).

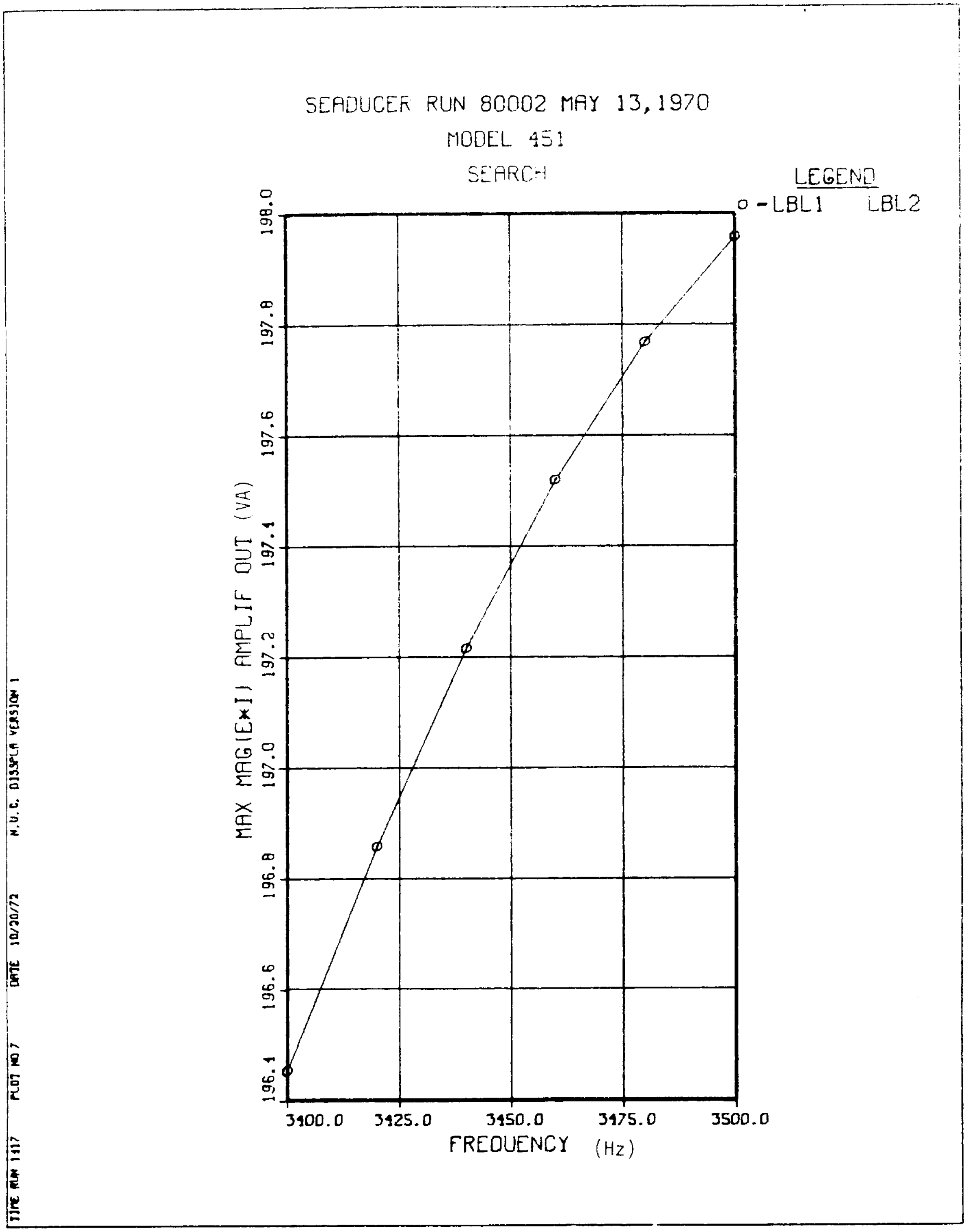

Figure D.5. (Continued).

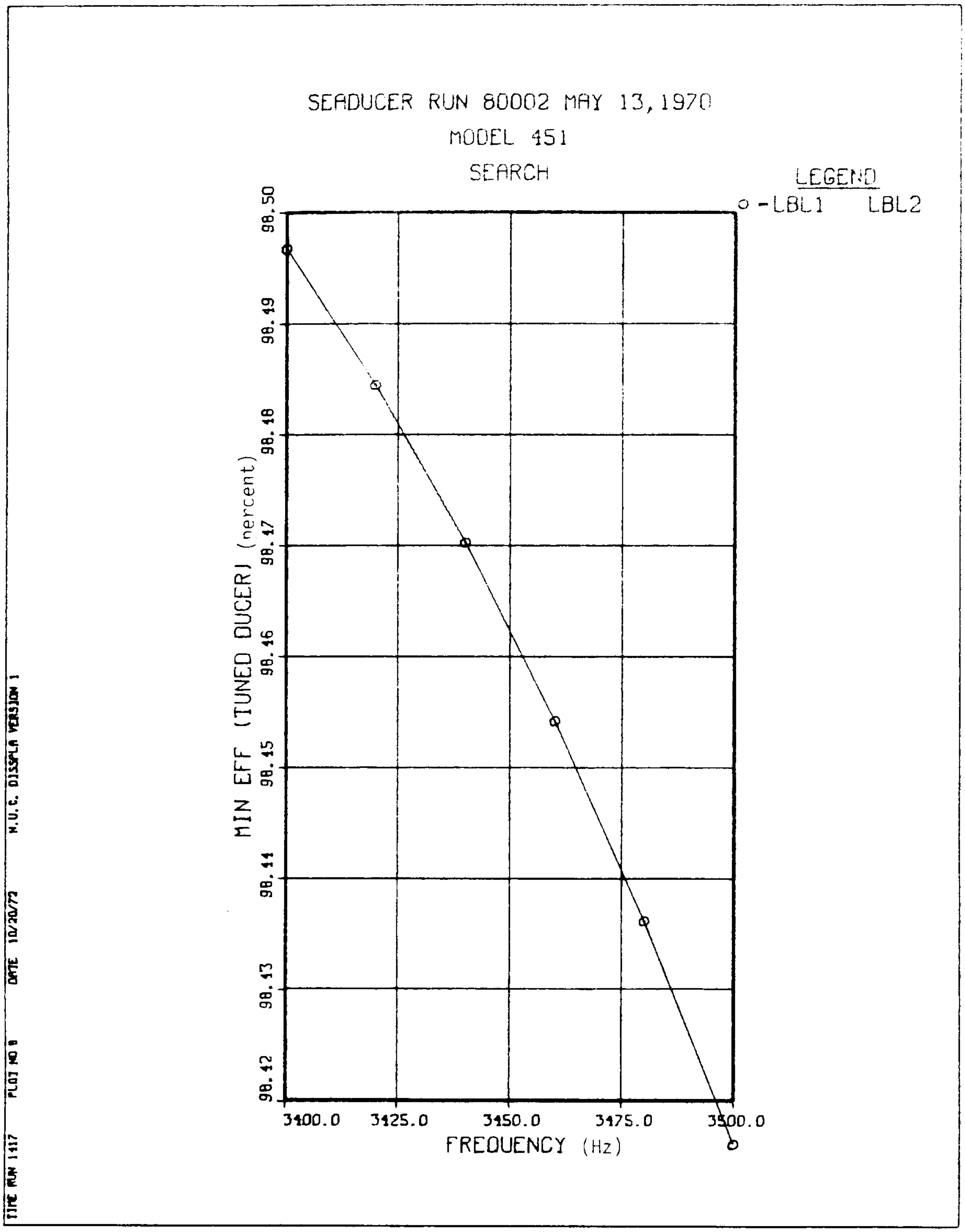

Figure D.5. (Continued).

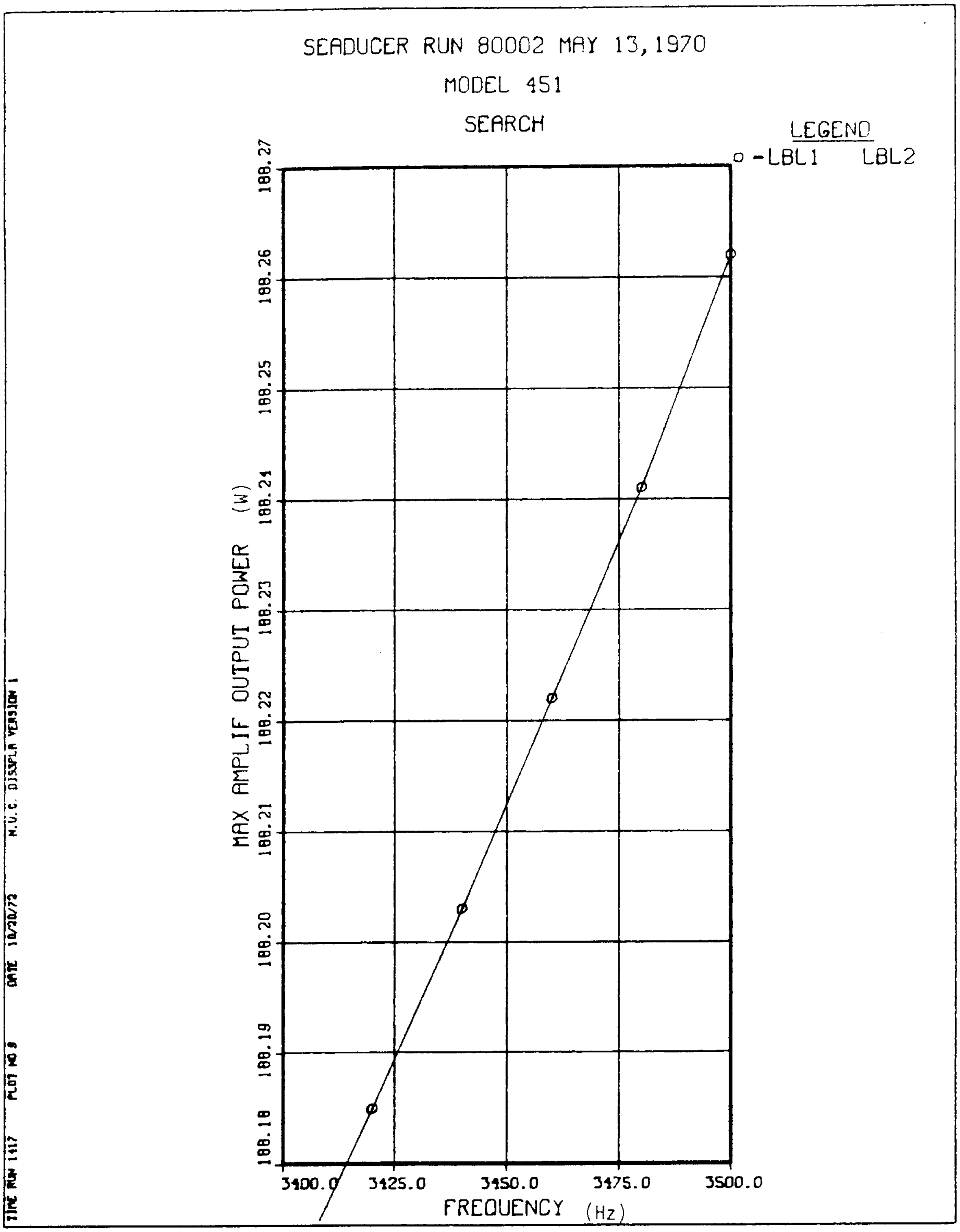

Figure D.5. (Continued).

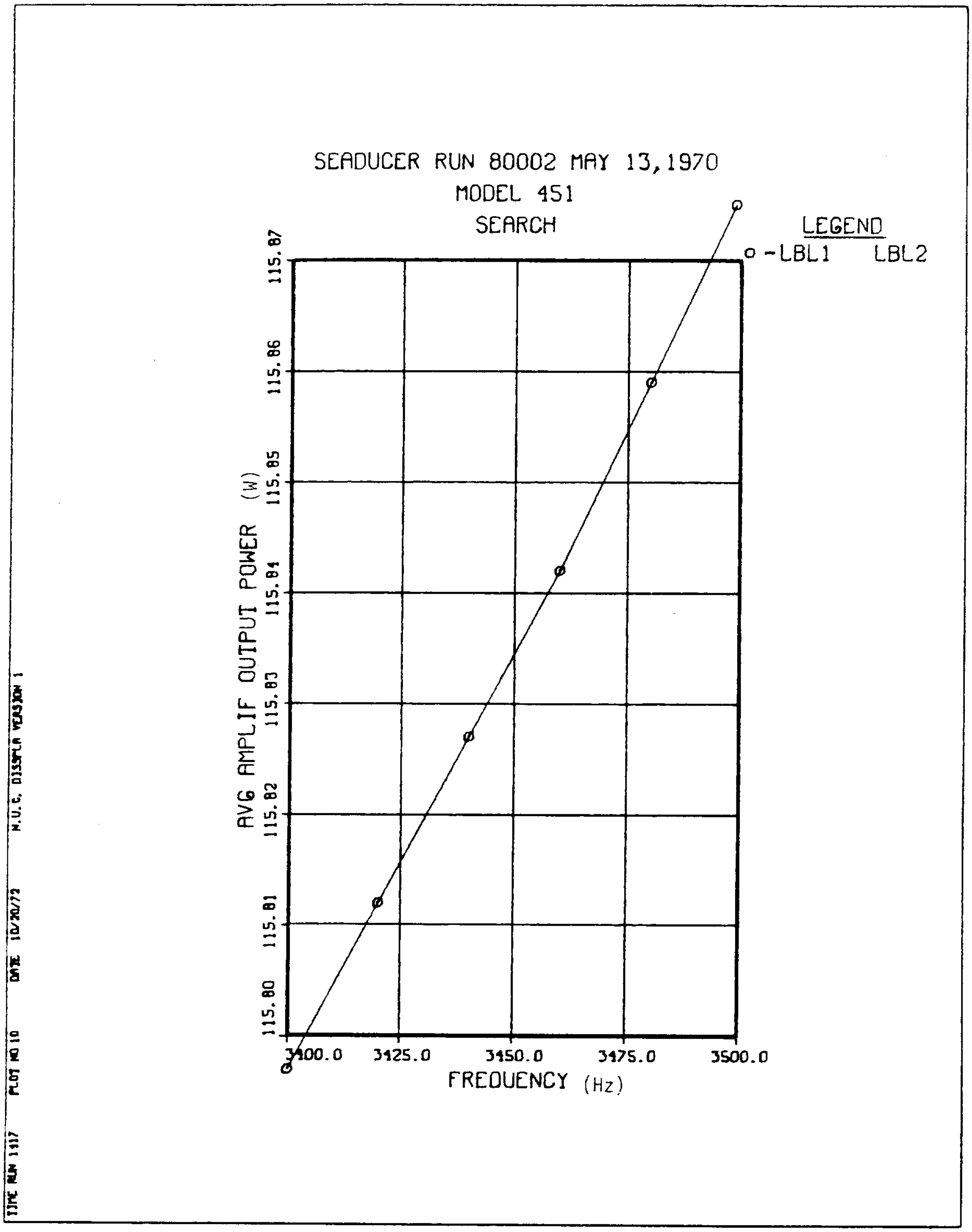

Figure D.5. (Continued).

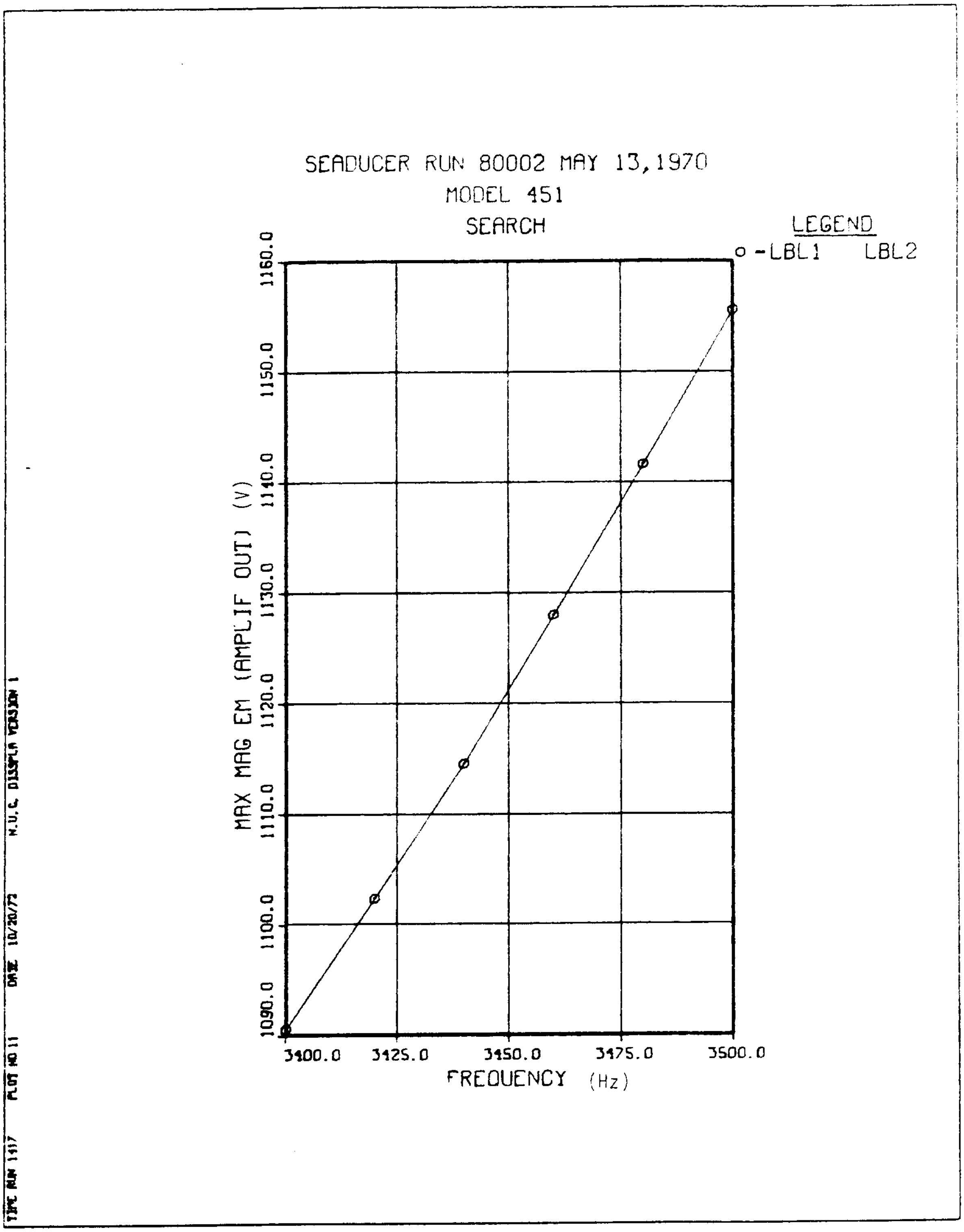

Figure D.5. (Continued).

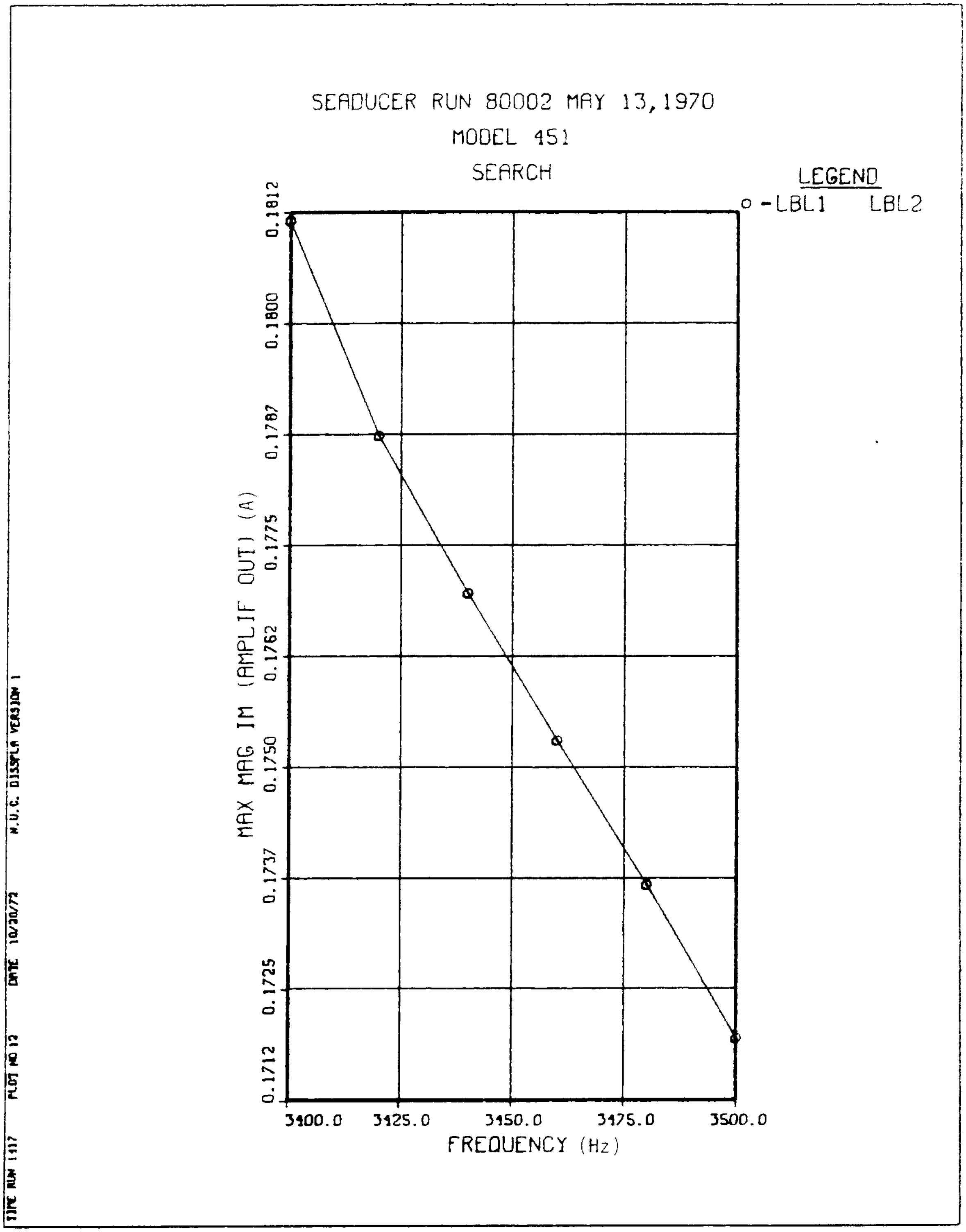

Figure D.5. (Continued).

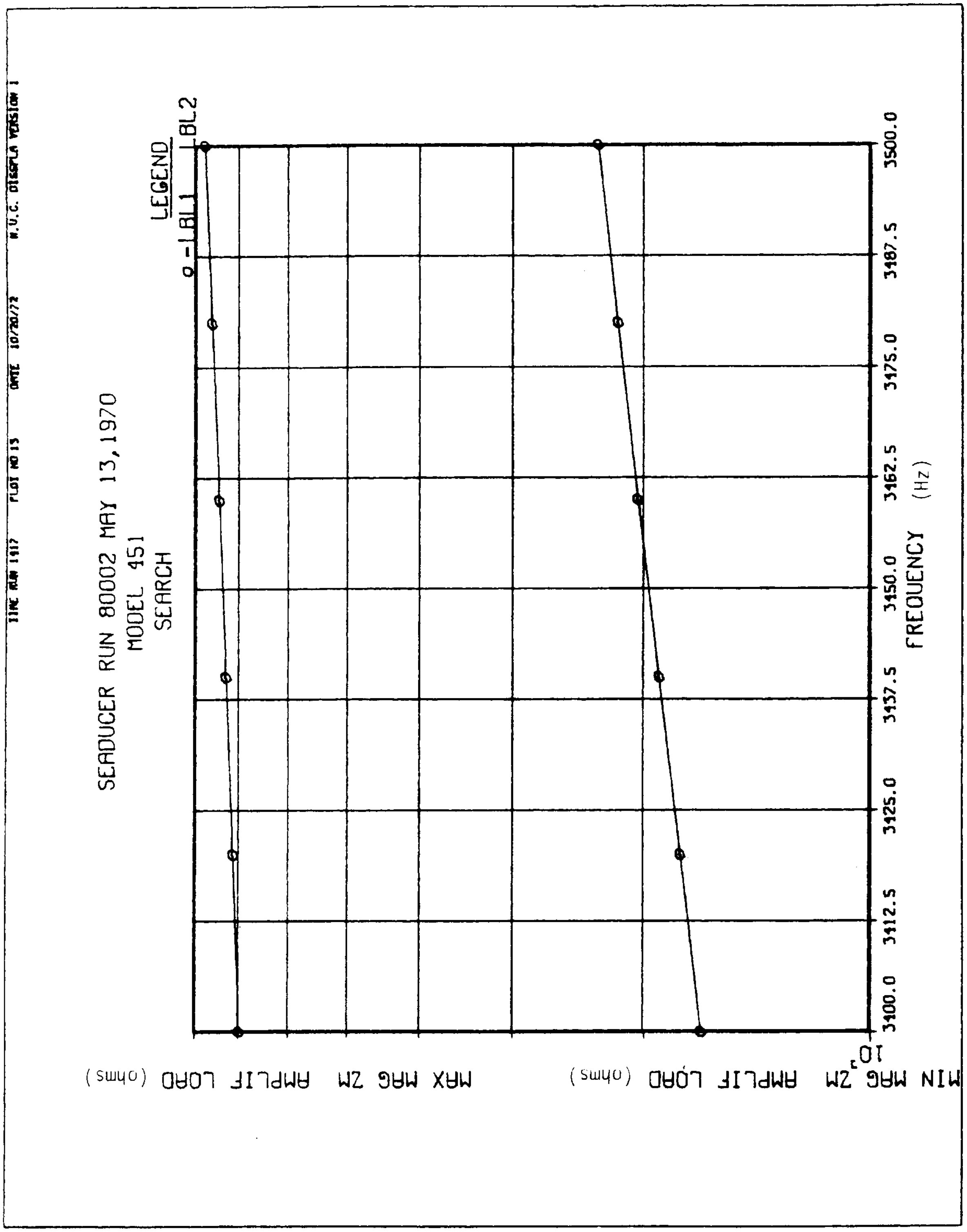

Figure D.5. (Continued).

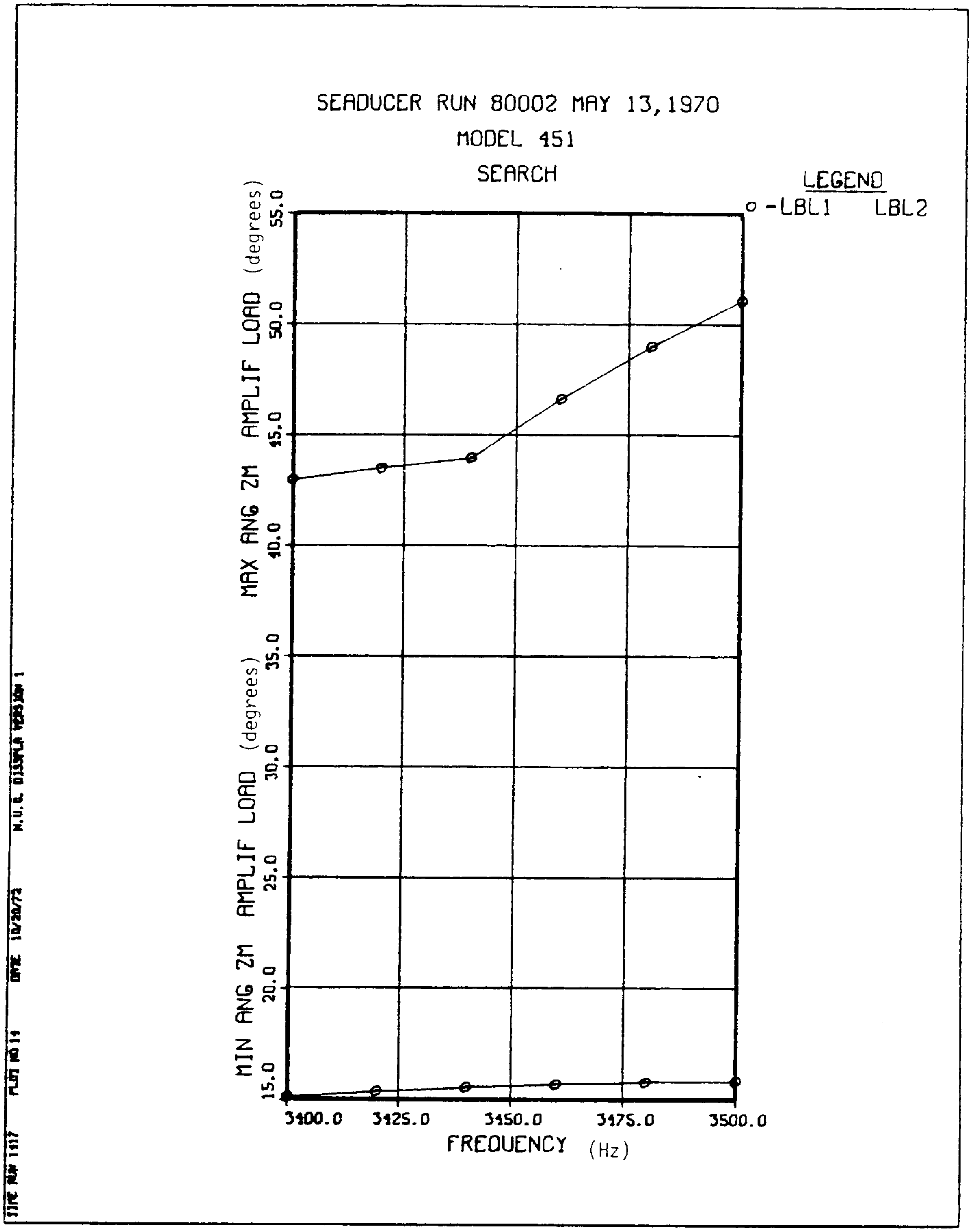

Figure D.5. (Continued).

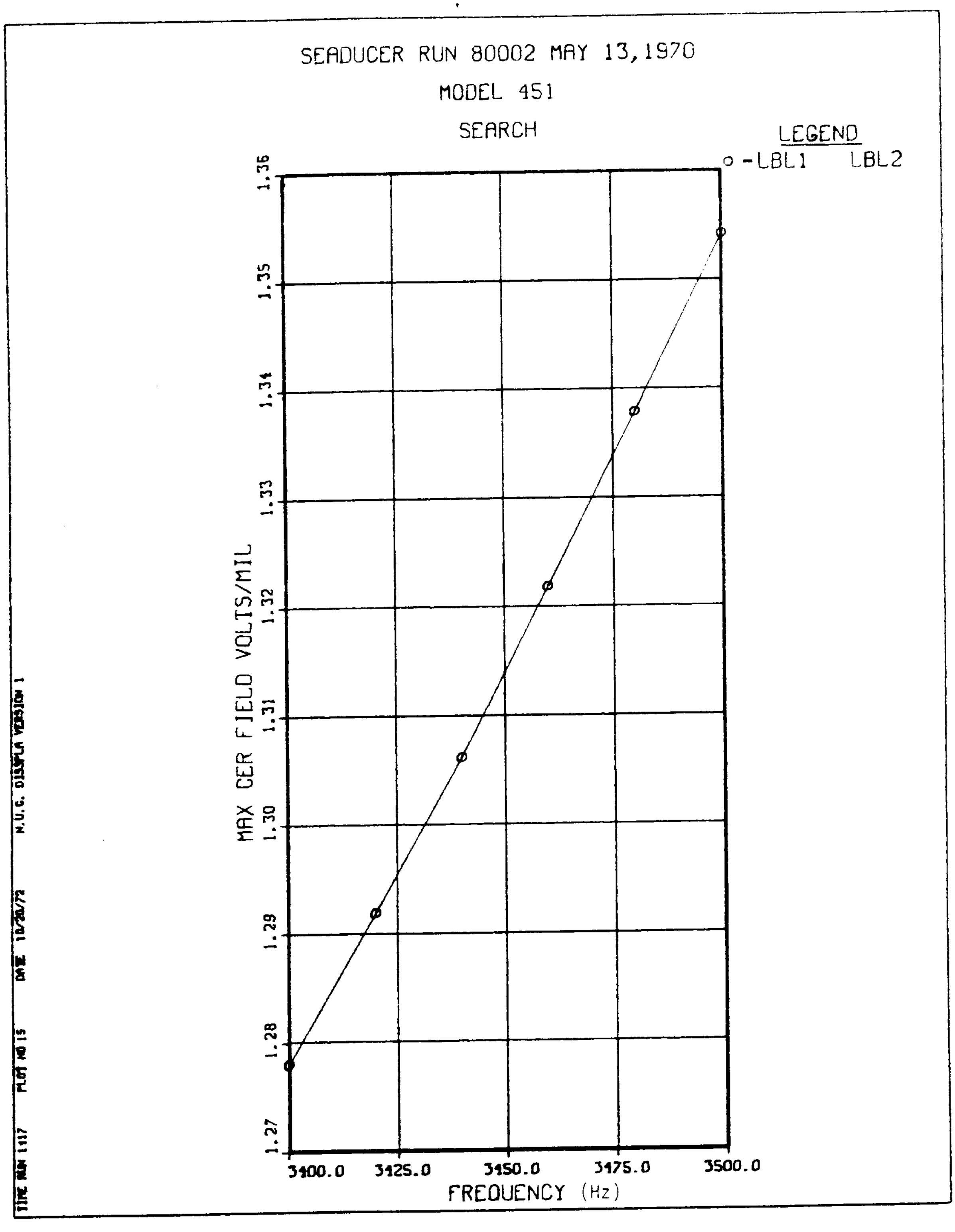

Figure D.5. (Continued).

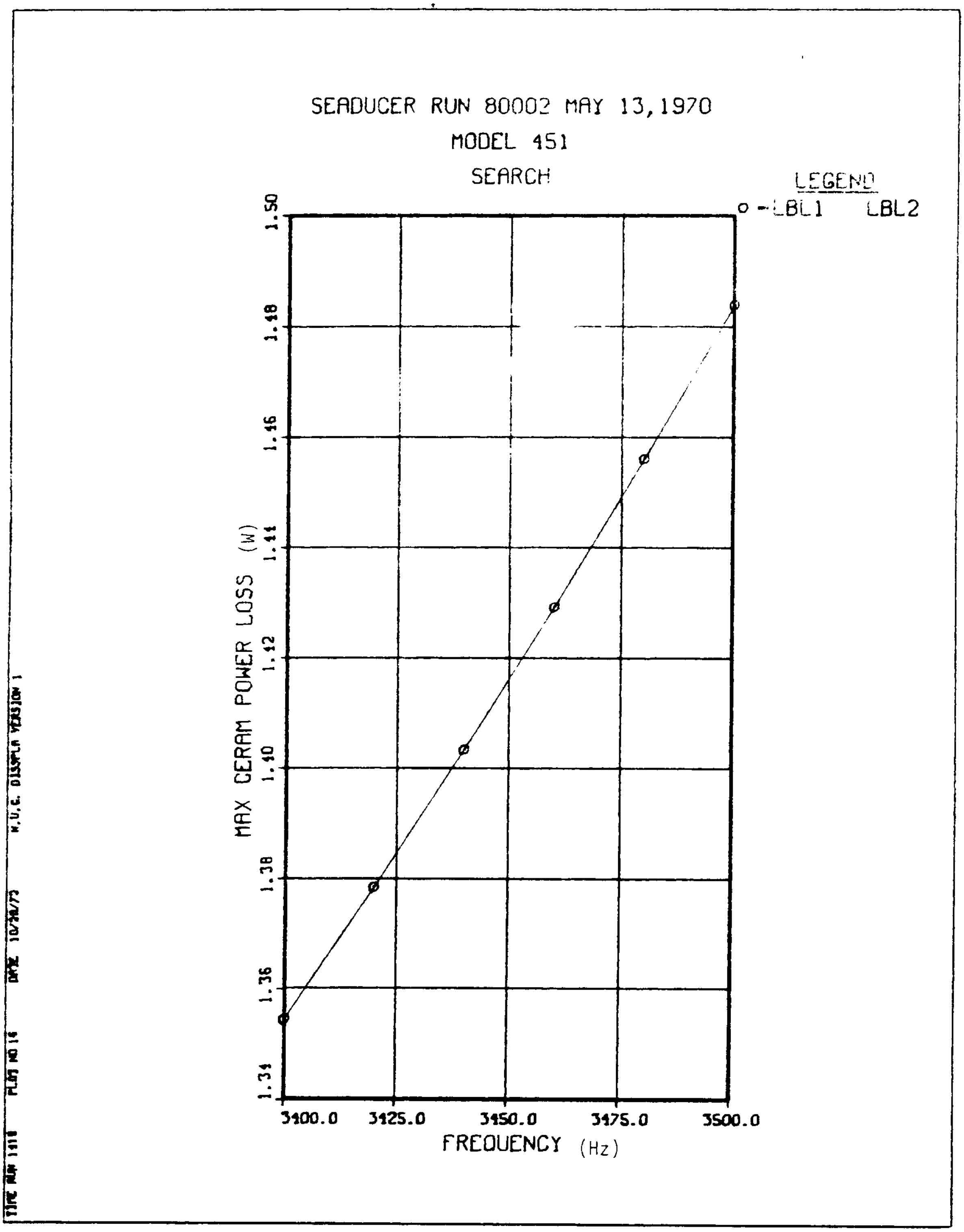

Figure D.5. (Continued).

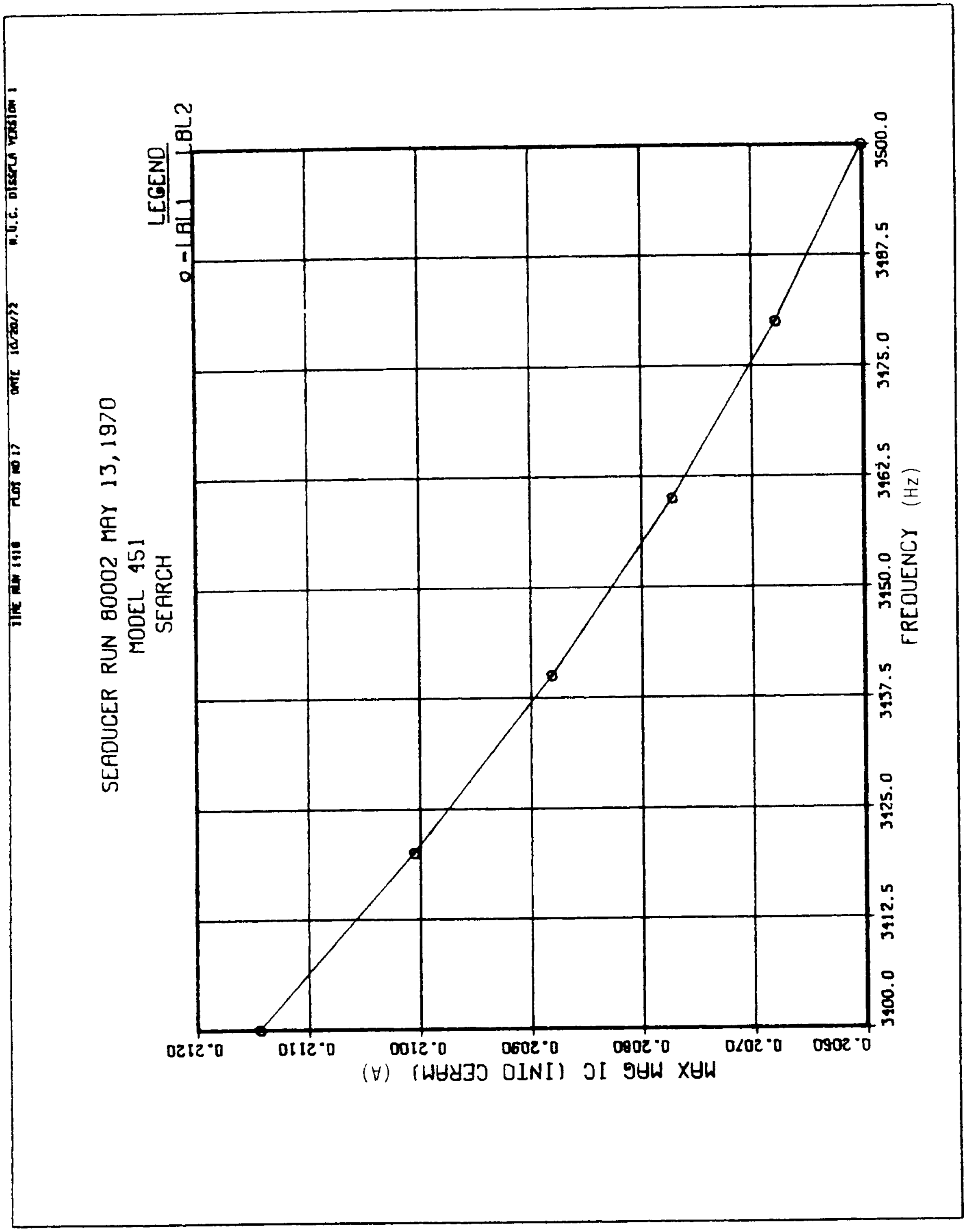

Figure D.5. (Continued).

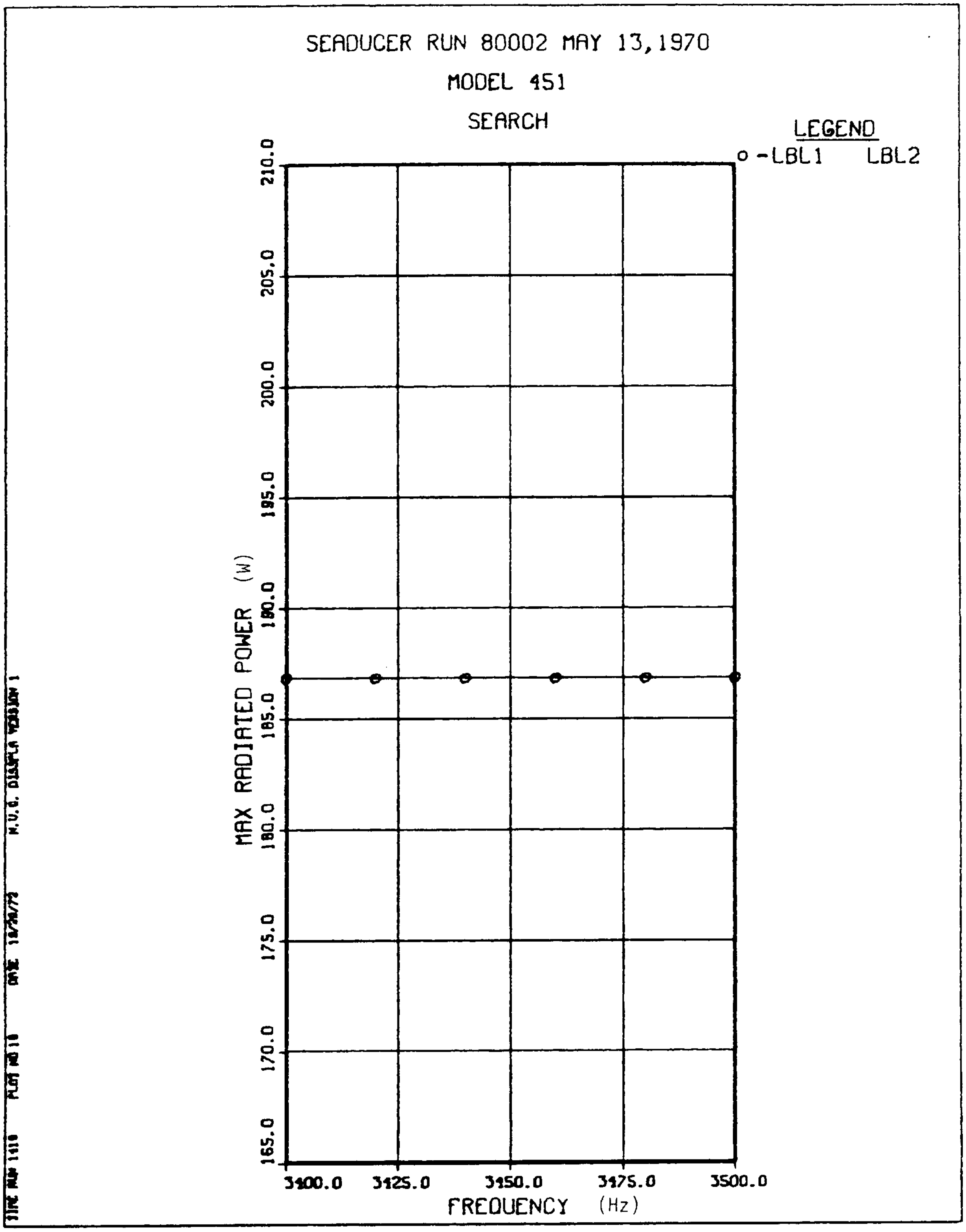

Figure D.5. (Continued).

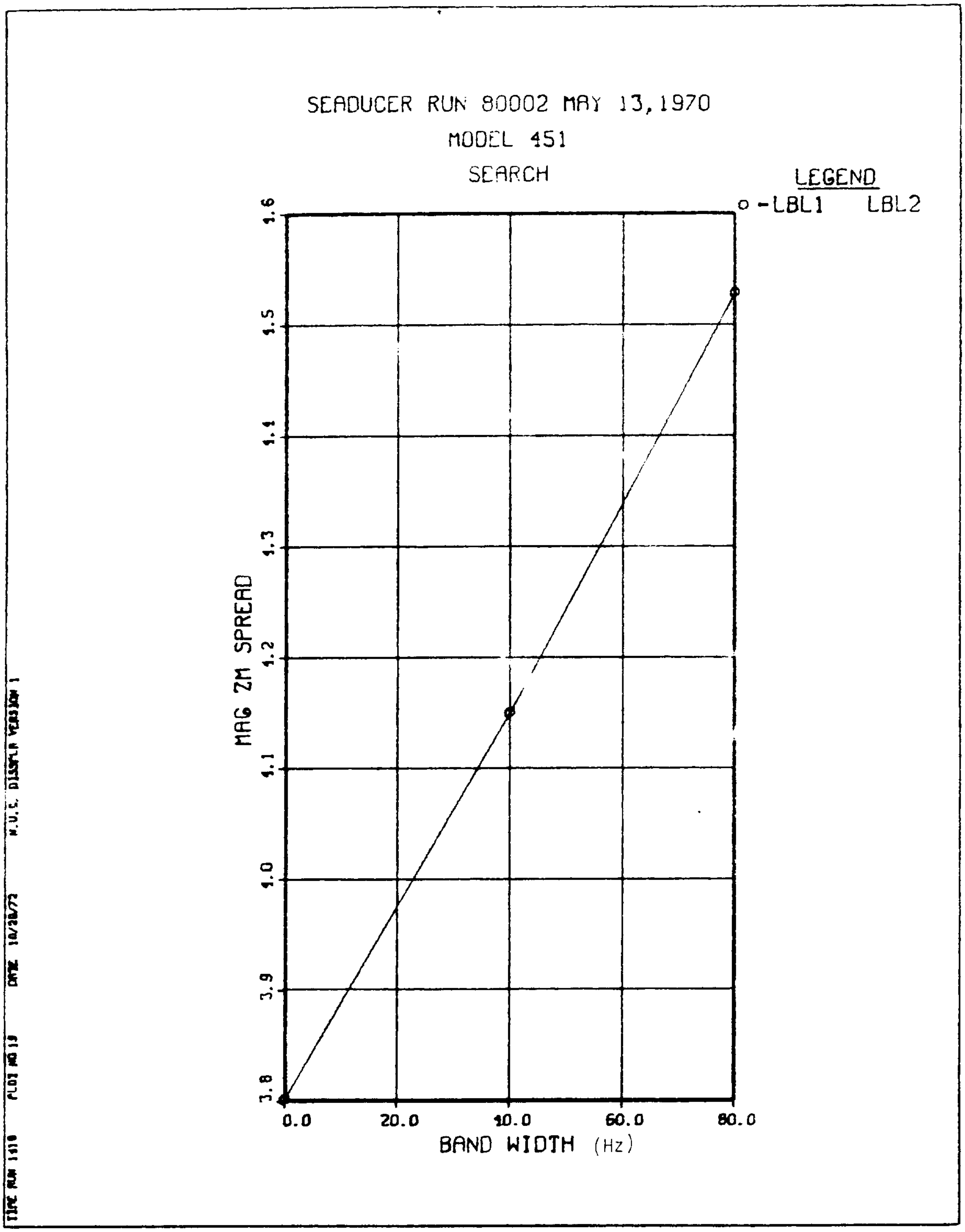

Figure D.5. (Continued).

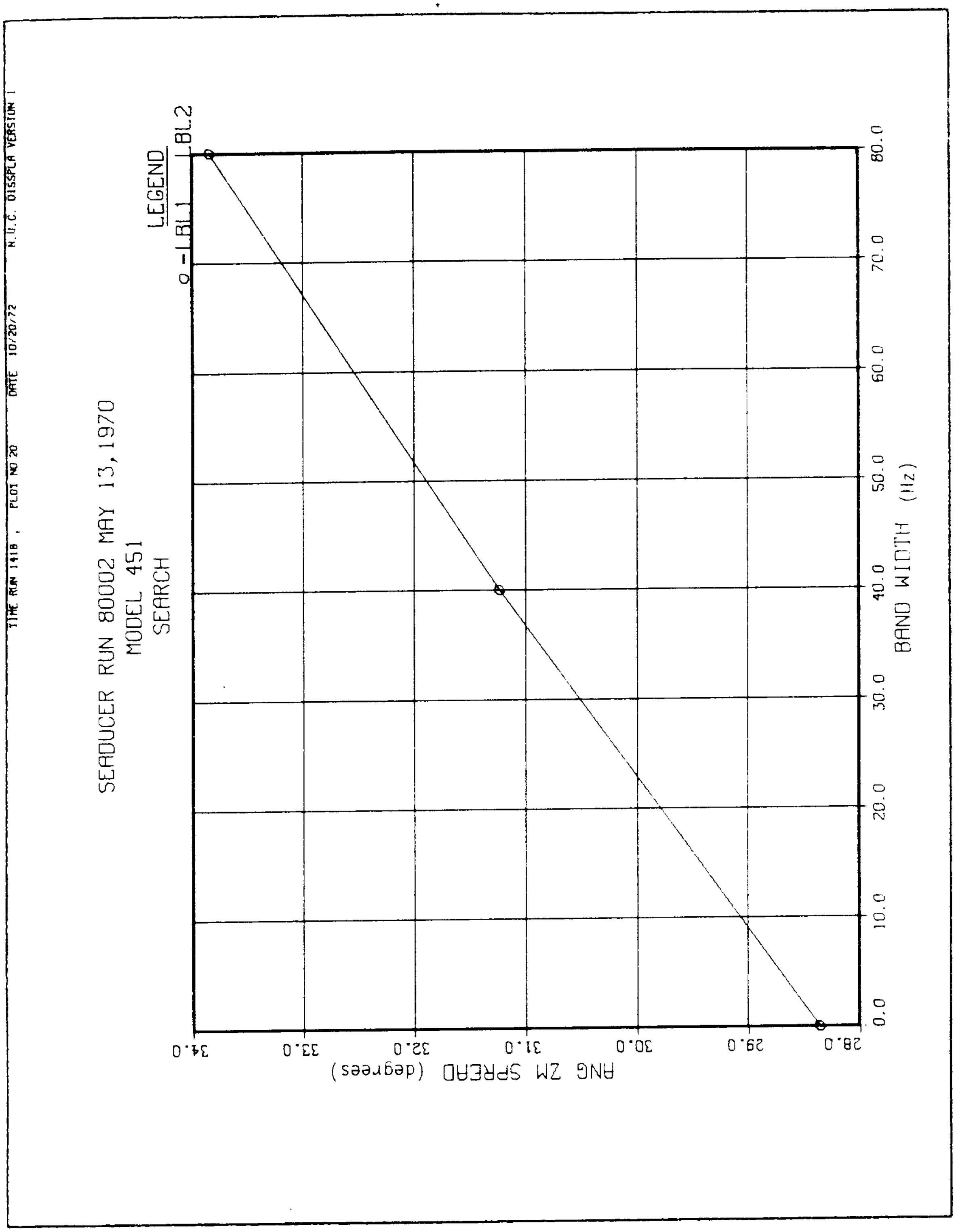

Figure D.5. (Continued).

APPENDIX E

FIND PARAMETERS EXAMPLE

The linear approximation iteration technique used to compute the set of ceramic parameters is described in this appendix. The technique designated "find parameters" computes the ceramic parameters $\left[s^{D}_{3333}, g_{333}, E^{T}_{33}, s^{D}_{3333}\ I, g_{333}\ I, E^{T}_{33}\ I \right]$ from the experimentally measured set of quantities [fm, fn, C (f_{LO}), |Ym|*, |Yn|, and D (f_{LO})], where

fm = the frequency of maximum admittance magnitude,

fn = the frequency of minimum admittance magnitude,

|Ym| = the electrical admittance magnitude at frequency fm,

|Yn| = the electrical admittance magnitude at frequency fn,

C = the electrical input parallel capacitance at a frequency f_{LO} which is below fm and near the lower frequency limit of the actual transponder operating frequency band (called CLO in program),

and D = the dissipation factor at the frequency f_{LO} (called CLOM in program).

**The absolute value signs will be omitted from Ym and Yn henceforth in this section even though absolute values are used.*

For simplicity of explanation of the method employed, the subscripts and superscripts on the ceramic parameters will be omitted in the remainder of this presentation, except to designate which set is being discussed. That is, the set of ceramic parameters will be {s, g, E, sI, gI, EI}.

The equations used to calculate the "measured" quantities from the parameters are dependent upon the exact configuration of the stack under investigation. The complete mathematical model of the stack will dictate the equations to be used. However, in general each of the "measured" quantities is a function of every material parameter, as implied by the following set of equations:

$$
\begin{aligned}
fm &= fm\,(s, g, E, sI, gI, EI) \\
fn &= fn\,(s, g, E, sI, gI, EI) \\
C\,(f_{LO}) &= C\,(s, g, E, sI, gI, EI) = \frac{\text{imag part of } Y_{f_{LO}}}{2 \times \pi \times f_{LO}} \\
Ym &= Ym\,(s, g, E, sI, gI, EI) \\
Yn &= Yn\,(s, g, E, sI, gI, EI) \\
D\,(f_{LO}) &= D\,(s, g, E, sI, gI, EI) = \frac{\text{real part of } Y_{f_{LO}}}{\text{imag part of } Y_{f_{LO}}}
\end{aligned}
\qquad (1)
$$

A useful relationship can be set up between these quantities by taking the total differentials, where f_{LO} is considered to be a constant for any particular case. This yields the following expression:

$$
\begin{bmatrix} dfm \\ dfn \\ dC \\ dYm \\ dYn \\ dD \end{bmatrix}
=
\begin{bmatrix}
\frac{\partial fm}{\partial s} & \frac{\partial fm}{\partial g} & \frac{\partial fm}{\partial E} & \frac{\partial fm}{\partial sI} & \frac{\partial fm}{\partial gI} & \frac{\partial fm}{\partial EI} \\
\frac{\partial fn}{\partial s} & \frac{\partial fn}{\partial g} & \cdots & & & \\
\frac{\partial C}{\partial s} & \vdots & \ddots & & & \\
\frac{\partial Ym}{\partial s} & \vdots & & & & \\
\frac{\partial Yn}{\partial s} & & & & & \\
\frac{\partial D}{\partial s} & & & & & \frac{\partial D}{\partial EI}
\end{bmatrix}
\begin{bmatrix} ds \\ dg \\ dE \\ dsI \\ dgI \\ dEI \end{bmatrix}
\tag{2}
$$

Although equation (2) is developed for infinitesimals, it should have approximate validity for finite differences. One estimates a set of material parameters $[s_o, g_o, E_o, sI_o, gI_o, EI_o]$. From this initial estimate one calculates a set of quantities, $\{fm_o, fn_o, C_o, Ym_o, Yn_o, D_o\}$, from the equations of the complete mathematical model.

A set of increments $\{\Delta s_o, \Delta g_o, \Delta E_o, \Delta sI_o, \Delta gI_o, \Delta EI_o\}$ is prescribed. A 10% change in s, g, E, sI, gI, and EI is used. One augments each of the initially estimated material parameters one at a time leaving the others alone. A new set, [fm, fn, C, Ym, Yn, D], is then calculated for each of the six augmentations. For example, when Δs_o is chosen to augment s_o and no other material parameters are augmented, one obtains the following set of values:

$$fm\,(s_o + \Delta s_o, g_o, E_o, sI_o, gI_o, EI_o)\,,$$

$$fn\,(s_o + \Delta s_o, g_o, E_o, sI_o, gI_o, EI_o)\,,$$

$$C\,(s_o + \Delta s_o, g_o, E_o, sI_o, gI_o, EI_o)\,,$$

$$Ym\,(s_o + \Delta s_o, g_o, E_o, sI_o, gI_o, EI_o)\,, \tag{3}$$

$$Yn\,(s_o + \Delta s_o, g_o, E_o, sI_o, gI_o, EI_o)\,,$$

and $$D\,(s_o + \Delta s_o, g_o, E_o, sI_o, gI_o, EI_o)\,.$$

If we subtract the quantities computed prior to augmentation, expand in a Taylor series and ignore the higher terms, we have

$$fm\,(s_o + \Delta s_o, g_o, \ldots) - fm_o = \frac{\partial fm}{\partial s}\Delta s_o, \text{ etc.}$$

Thus, the following linear approximations are obtained:

$$\frac{\partial fm}{\partial s} \doteq \frac{fm\,(s_o + \Delta s_o, g, \ldots) - fm}{\Delta s_o}, \ldots \frac{\partial fm}{\partial EI} \doteq \frac{fm\,(s_o, \ldots EI_o + \Delta EI_o) - fm}{\Delta EI_o}$$

$$\frac{\partial fn}{\partial s} \doteq \frac{fn\,(s_o + \Delta s_o, g_o, \ldots) - fn}{\Delta s_o} \tag{4}$$

$$\vdots$$

$$\frac{\partial D}{\partial s} \doteq \frac{D\,(s_o + \Delta s_o, g_o, \ldots) - D}{\Delta s_o} \qquad \frac{\partial D}{\partial EI} \doteq \frac{D\,(s_o, \ldots EI_o + \Delta EI_o) - D}{\Delta EI_o}$$

By this procedure, a numerical value is obtained for each of the entries of the partial differential matrix described above in equation (1). After this matrix is obtained, its inverse matrix, A, is found. Now one can write the finite differences of the set [s, g, E, sI, gI, EI] in terms of the finite differences of the set [fm, fn, C, Ym, Yn, D]. This equation has the form

$$\begin{bmatrix} \Delta s \\ \Delta g \\ \Delta E \\ \Delta SI \\ \Delta gI \\ \Delta EI \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{13} & A_{14} & A_{15} & A_{16} \\ A_{21} & A_{22} & A_{23} & A_{24} & A_{25} & A_{26} \\ A_{31} & & & & & \\ A_{41} & & & & & \\ A_{51} & & & & & \\ A_{61} & & & & & A_{66} \end{bmatrix} \begin{bmatrix} \Delta fm \\ \Delta fn \\ \Delta C \\ \Delta Ym \\ \Delta Yn \\ \Delta D \end{bmatrix} \qquad (5)$$

One now chooses Δfm to be the difference between the experimentally measured value, fm_{ex} and the value fm_o calculated from the estimated ceramic parameters, and likewise for the other quantities. Thus

$$\Delta fm = fm_{ex} - fm_o,$$

$$\Delta fn = fn_{ex} - fn_o,$$

$$\Delta C = C_{ex} - C_o,$$

$$\Delta Ym = Ym_{ex} - Ym_o, \qquad (6)$$

$$\Delta Yn = Yn_{ex} - Yn_o,$$

and $$\Delta D = D_{ex} - D_o.$$

After the matrix multiplication indicated in equation (5) is completed, the resulting changes in the material parameters [Δs, Δg, ΔE, ΔsI, ΔgI, ΔEI] are added to the initial estimates [s_o, g_o, E_o, SI, gI_o, EI_o] to obtain the first corrected set of material parameters [s_1, g_1, E_1, sI_1, gI_1, EI_1]. If the equations were nothing more than a linear set of equations, this corrected set of material parameters would be the exact solution which goes with the experimentally measured quantities. But since this is not the case, this corrected set of material parameters [s_1, g_1, E_1, sI_1, gI_1, EI_1] is substituted into equation (1) to obtain a second calculated set [fm_1, fn_1, C_1, Ym_1, Yn_1, D_1]. To insure a refinement, a new set of increments [Δs_1, Δg_1, ΔE_1, ΔsI_1, ΔgI_1, ΔEI_1] is also formed, each member of which is formed from the old increments by multiplying such increments by 0.1: $\Delta s_1 = \Delta s_o .1$, etc. Thus, starting with the procedure described below equation (2), this iteration may be repeated as many times as desired. The iteration is terminated if each of the following terms is less than the corresponding member of some preset list of increments.

$$\left|\frac{fm_{ex} - fm}{fm_{ex}}\right| < \delta fm$$

$$\left|\frac{fn_{ex} - fn}{fn_{ex}}\right| < \delta fn$$

$$\left|\frac{C_{ex} - C}{C_{ex}}\right| < \delta C \tag{7}$$

$$\left|\frac{Ym_{ex} - Ym}{Ym_{ex}}\right| < \delta Ym$$

$$\left|\frac{Yn_{ex} - Yn}{Yn_{ex}}\right| < \delta Yn$$

$$\left|\frac{D_{ex} - D}{D_{ex}}\right| < \delta D$$

This test is made just following the calculation of each corrected set of material parameters. With $\delta fm = \delta fn = \delta C = .3*10^{-4}$ and $\delta Ym = \delta Yn = \delta D = 10^{-3}$, not more than two iterations are in general necessary if one uses reasonably good initial estimates of the material parameters.

A word of caution is appropriate here. The program can converge to impossible parameters if there are errors in the transducer input data or experimental data. Therefore, close inspection of the results should be made to insure validity.

Figure E.1 shows a diagram of the transducer used in the find parameters example, and the associated interconnection schematic. Figure E.2 shows a listing of the required control routine and printed output.

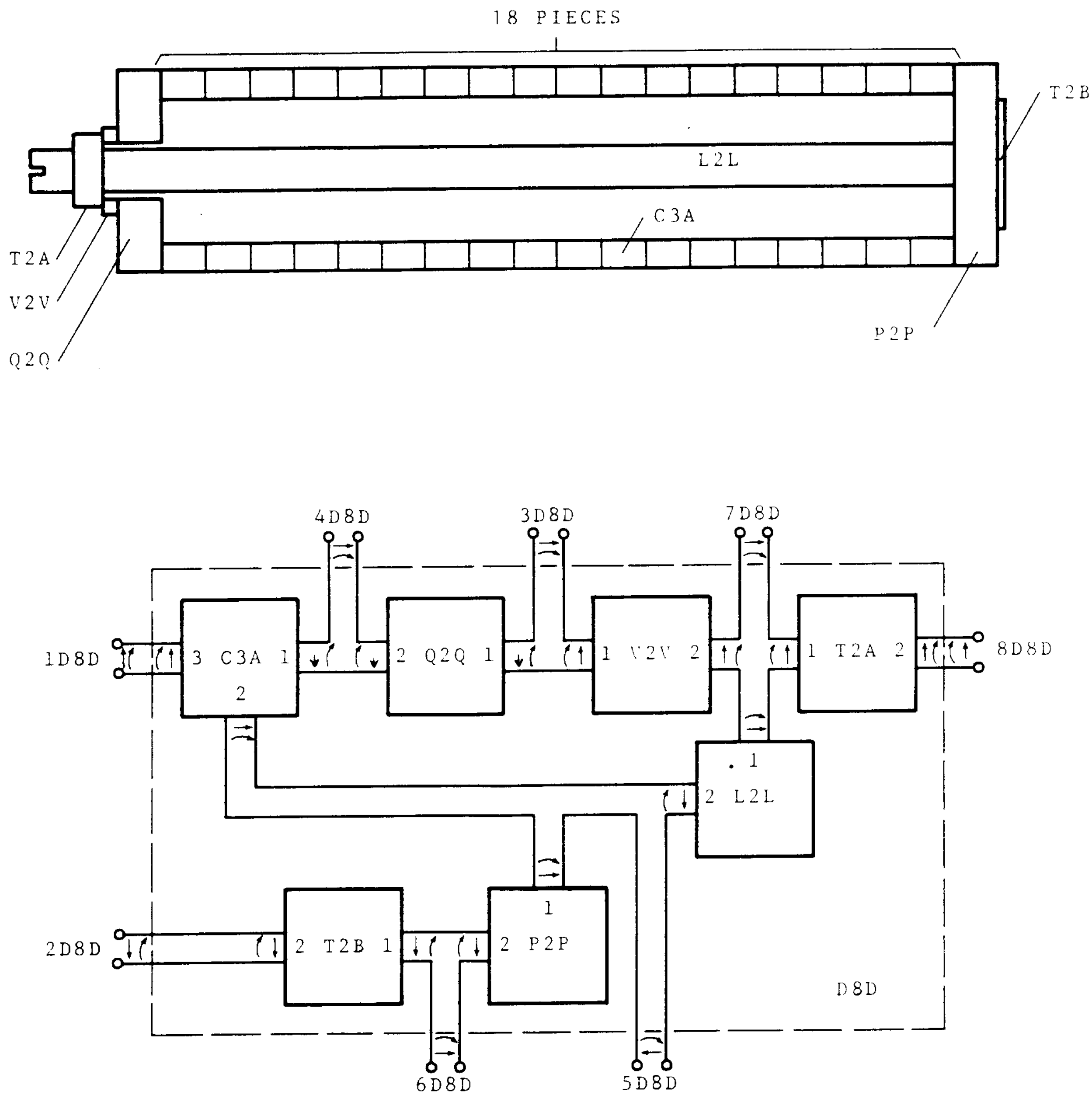

Figure E.1. Transducer Diagram And Interconnection Schematic.

Figure E.2.

Listing and Output of the Control Routine Used in Find Parameters.

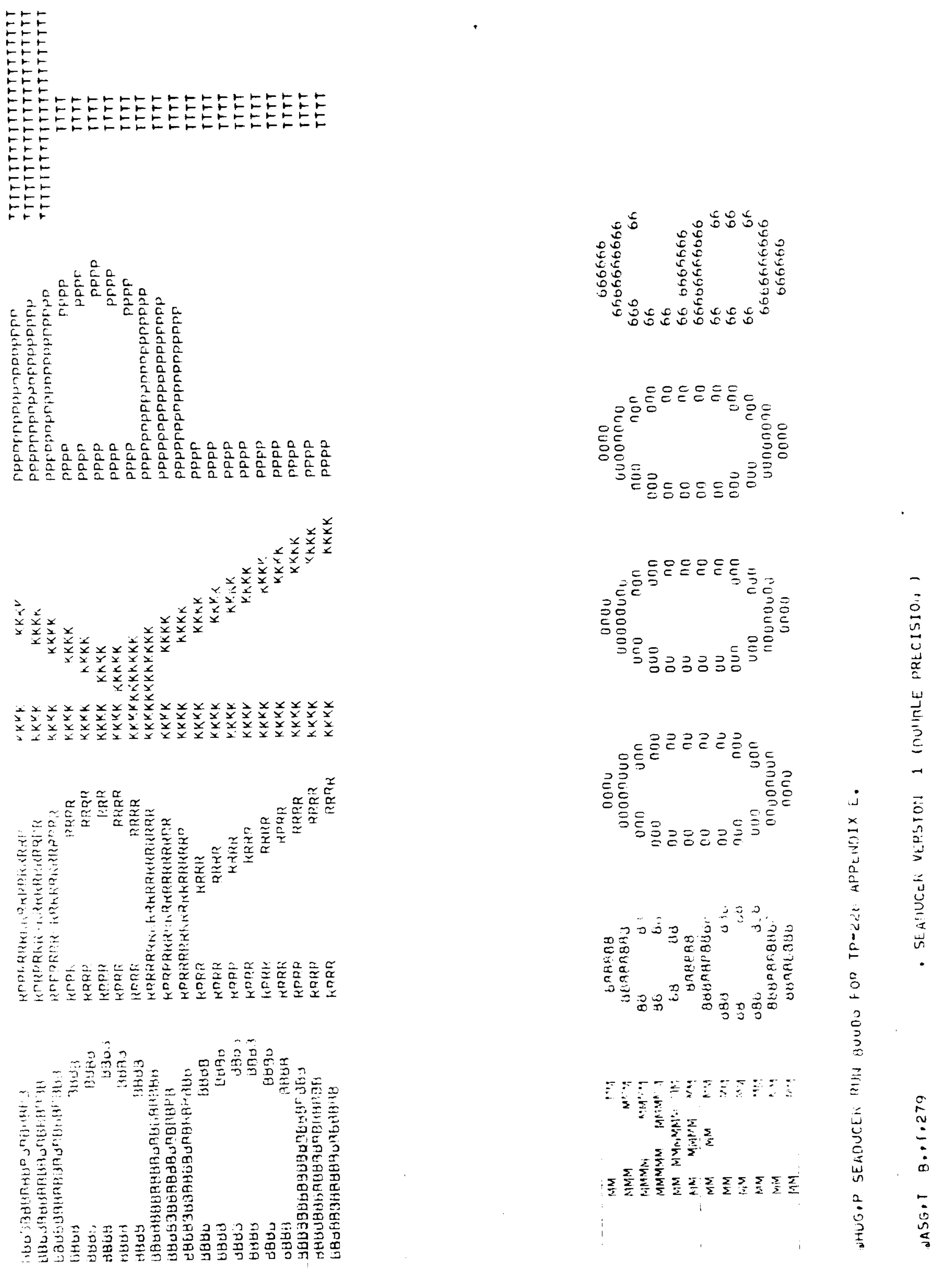

Figure E.2. (Continued).

```
SEADUCER RUN 80006 FOR TP-228 APPENDIX E                                DATE 102072        PAGE     1

@COPIN B.,TPF$.
FURPUR 023A-10/20-13:35
 112 SYM  112 REL

@FREE  B.
```

Figure E.2. (Continued).

```
WFOR,IS      CONTRL,CONTRL
FOR 0010-10/20/72-13:36:55 (,0)

      MAIN PROGRAM

      STORAGE USED: CODE(1) 000333; DATA(0) 000223; BLANK COMMON(2) 003720

       COMMON BLOCKS:

       0003    BASIC8 000006
       0004    DTATOT 000001

      EXTERNAL REFERENCES (BLOCK, NAME)

       0005    SETCLK
       0006    PAGE
       0007    STRLIN
       0010    LDPORT
       0011    LDDT1
       0012    LDDT2
       0013    LDDT11
       0014    TIME
       0015    ENDPRM
       0016    PRPTBL
       0017    PRCTLG
       0020    NINTR$
       0021    NPRT$
       0022    NIO2$
       0023    NSTOP$

      STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

       0000   000000 5F         0002 D 000000 DATA       0003 D 000000 DF         0003 D 000002 DOMEGA     0003 D 000004 DPI
       0004 I 000000 MXDATA


 00101       1*           DOUBLE PRECISION DATA                                          CONTRL
 00103       2*           DOUBLE PRECISION DF, DOMEGA, DPI                               CONTRL
 00104       3*           COMMON / BASIC 8 / D F, D OMEGA, D PI
 00105       4*           COMMON / DTA TOT / MX DATA
 00106       5*           COMMON /         / DATA(1000)
 00107       6*           MX DATA = 1000
 00110       7*
 00110       8*           CALL SETCLK
 00111       9*           CALL PAGE
 00112      10*           CALL STR LIN
 00113      11*           PRINT 5
 00115      12*         5 FORMAT(' SEADUCER RUN 80006 (LIKE MOD 7 RUN 70443) MAY 14,1970'/
 00115      13*          /        ' TO CHECKOUT FIND PARAMETERS ')
 00116      14*
 00116      15*           CALL LD PORT( 'S', '1D8D, 3C3A,$' )
 00117      16*           CALL LD PORT( 'S', '2D8D, 2T2B,$' )
 00120      17*           CALL LD PORT( 'S', '3D8D, 1Q2Q, 1V2V,$')
```

Figure E.2. (Continued).

```
00121     18*      CALL LD PORT( 'S', '4D8D, 1C3A,   -+2Q2Q,$' )
00122     19*      CALL LD PORT( 'S', '5D8D, 1P2P, -+2L2L, -+2C3A,$' )
00123     20*      CALL LD PORT( 'S', '6D8D, 2P2P, -+1T2B,$' )
00124     21*      CALL LD PORT( 'S', '7D8D, 1L2L, 1T2A, -+2V2V,$' )
00125     22*      CALL LD PORT( 'S', '8D8D, 2T2A,$' )
00126     23*
00126     24*      CALL LD DT 1
00126     25*     / ('T2A1$', 7663.51, .0766601E-2,0.,0., 3.55601E-3, 5043.8,0.,0.)
00127     26*      CALL LD DT 2
00127     27*     / ('T2A2$', 7663.51, .0766601E-2,0.,0.,
00127     28*     /                     .0467602E-2,0.,0., 4.06401E-3, 5043.8,0.,0.)
00130     29*      CALL LD DT 1
00130     30*     / ('T2A3$', 7663.51, .0467602E-2,0.,0., 10.4648E-3, 5043.8,0.,0.)
00131     31*      CALL LD DT 1
00131     32*     / ('V2V1$', 7696.86, .101971E-2,0.,0., 3.14961E-3, 5116.0,0.,0.)
00132     33*      CALL LD DT 1
00132     34*     / ('Q2Q1$', 7822.86, .427004E-2,0.,0., 31.7628E-3, 5116.0,0.,0.)
00133     35*      CALL LD DT 1
00133     36*     / ('P2P1$', 7919.77, .455735E-2,0.,0., 31.7628E-3, 5116.0,0.,0.)
00134     37*      CALL LD DT 1
00134     38*     / ('T2B1$', 7807.65, .0255E-2,0.,0., 3.73381E-3, 5043.8,0.,0.)
00135     39*      CALL LD DT 1
00135     40*     / ('L2L1$', 7807.65, .0255E-2,0.,0., 10.4902E-3, 5043.8,0.,0.)
00136     41*      CALL LD DT 1
00136     42*     / ('L2L2$', 7807.65, .0285785E-2,0.,0., 35.1791E-3, 5043.8,0.,0.)
00137     43*      CALL LD DT 1
00137     44*     / ('L2L3$', 7807.65, .0198250E-2,0.,0., 329.286E-3, 5043.8,0.,0.)
00140     45*      CALL LD DT 1
00140     46*     / ('L2L4$', 7807.65, .0255E-2,0.,0., 3.87351E-3, 5043.8,0.,0.)
00141     47*      CALL LD DT 11('C3A$', 18, 7555., .253355E-2,0.,0., 19.1065E-3,
00141     48*     E   1325.1800, 0.D0, .002295D0,
00141     49*     G   .02205D0, 0.D0, .0003553D0,
00141     50*     S   .90616D-11, 0.D0, .00173ID0 )
00142     51*
00142     52*      CALL TIME
00143     53*      CALL END PRM( 'CA', 3526., 4268., .130, 2.43E-6,
00143     54*     /                        26261.3E-12, .0017065, 500., 3 )
00144     55*      CALL TIME
00145     56*
00145     57*      CALL PAGE
00146     58*      CALL PR PTML
00147     59*      CALL PAGE
00150     60*      CALL PR CTLG
00151     61*      CALL PAGE
00152     62*      CALL TIME
00153     63*      STOP
00154     64*      END

      END OF COMPILATION:          NO  DIAGNOSTICS.
```

Figure E.2. (Continued).

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@TOP — TIME: 13:37:06 — DATE: 20 OCT 72 — CPU TIME (MILSEC): 1927

@PREP TPF$
FURPUR 023A-10/20-13:37

@PRT,T TPF$.

LM6010314522*TPF$ ELEMENT TABLE

D	NAME	VERSION	TYPE	DATE	TIME	SEQ #	SIZE-PRE	TEXT	(CYCLE	WORD)	PSRMODE	LOCATION
*	CONTRL		FOR SYMB	28 MAR 72	23:16:43	1		26	5	0	1	1792
*	CONTRL		RELOCATABLE	28 MAR 72	23:16:45	2	3	38				1818
	LDPORT		FOR SYMB	28 MAR 72	23:16:45	3		20	5	0	1	1859
	LDPORT		RELOCATABLE	28 MAR 72	23:16:47	4	2	15				1879
	BLDMTR		FOR SYMB	28 MAR 72	23:16:48	5		19	5	0	1	1896
	BLDMTR		RELOCATABLE	28 MAR 72	23:16:49	6	2	11				1915
	BLDKKL		FOR SYMB	28 MAR 72	23:16:50	7		26	5	0	1	1928
	BLDKKL		RELOCATABLE	28 MAR 72	23:16:52	8	3	16				1954
	RDCPRT		FOR SYMB	28 MAR 72	23:16:53	9		39	5	0	1	1973
	RDCPRT		RELOCATABLE	28 MAR 72	23:16:55	10	2	30				2012
	LDFREQ		FOR SYMB	28 MAR 72	23:16:56	11		4	5	0	1	2044
	LDFREQ		RELOCATABLE	28 MAR 72	23:16:57	12	2	3				2048
	UPPTBL		FOR SYMB	28 MAR 72	23:16:58	13		11	5	0	1	2053
	UPPTBL		RELOCATABLE	28 MAR 72	23:17:00	14	2	7				2064
	FNDLCJ		FOR SYMB	28 MAR 72	23:17:00	15		17	5	0	1	2073
	FNDLCJ		RELOCATABLE	28 MAR 72	23:17:02	16	2	11				2090
	ALOCAT		FOR SYMB	28 MAR 72	23:17:03	17		8	5	0	1	2103
	ALOCAT		RELOCATABLE	28 MAR 72	23:17:04	18	2	4				2111
	CHKSTR		FOR SYMB	28 MAR 72	23:17:04	19		3	5	0	1	2117
	CHKSTR		RELOCATABLE	28 MAR 72	23:17:06	20	2	3				2120
	FNDNET		FOR SYMB	28 MAR 72	23:17:06	21		9	5	0	1	2125
	FNDNET		RELOCATABLE	28 MAR 72	23:17:07	22	1	6				2134
	LOCMTR		FOR SYMB	28 MAR 72	23:17:08	23		4	5	0	1	2141
	LOCMTR		RELOCATABLE	28 MAR 72	23:17:09	24	1	3				2145
	LOCNAM		FOR SYMB	28 MAR 72	23:17:10	25		3	5	0	1	2149
	LOCNAM		RELOCATABLE	28 MAR 72	23:17:11	26	1	3				2152
	FNDMTR		FOR SYMB	28 MAR 72	23:17:12	27		4	5	0	1	2156
	FNDMTR		RELOCATABLE	28 MAR 72	23:17:13	28	1	3				2160
	FNDNAM		FOR SYMB	28 MAR 72	23:17:13	29		3	5	0	1	2164
	FNDNAM		RELOCATABLE	28 MAR 72	23:17:15	30	1	3				2167
	CASCDE		FOR SYMB	28 MAR 72	23:17:15	31		16	5	0	1	2171
	CASCDE		RELOCATABLE	28 MAR 72	23:17:17	32	2	9				2187
	TYPCAL		FOR SYMB	28 MAR 72	23:17:18	33		15	5	0	1	2198
	TYPCAL		RELOCATABLE	28 MAR 72	23:17:19	34	2	12				2213
	LDDT1		FOR SYMB	28 MAR 72	23:17:20	35		23	5	0	1	2227
	LDDT1		RELOCATABLE	28 MAR 72	23:17:22	36	2	17				2250
	TYPE1		FOR SYMB	28 MAR 72	23:17:23	37		13	5	0	1	2269
	TYPE1		RELOCATABLE	28 MAR 72	23:17:24	38	2	9				2282
	LDDT2		FOR SYMB	28 MAR 72	23:17:25	39		25	5	0	1	2293
	LDDT2		RELOCATABLE	28 MAR 72	23:17:27	40	2	19				2318
	TYPE2		FOR SYMB	28 MAR 72	23:17:28	41		17	5	0	1	2339
	TYPE2		RELOCATABLE	28 MAR 72	23:17:30	42	2	13				2356
	LDDT4		FOR SYMB	28 MAR 72	23:17:30	43		19	5	0	1	2371

Figure E.2. (Continued).

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LDDT4	RELOCATABLE	28 MAR 72	23:17:32	44	2	13				2390
LDDT5	FOR SYMB	28 MAR 72	23:17:33	45		17	5	0	1	2405
LDDT5	RELOCATABLE	28 MAR 72	23:17:34	46	2	11				2422
LDDT7	FOR SYMB	28 MAR 72	23:17:36	47		51	5	0	1	2435
LDDT7	RELOCATABLE	28 MAR 72	23:17:38	48	2	30				2486
TYPE7	FOR SYMB	28 MAR 72	23:17:39	49		28	5	0	1	2518
TYPE7	RELOCATABLE	28 MAR 72	23:17:42	50	1	23				2546
LDDT8	FOR SYMB	28 MAR 72	23:17:42	51		22	5	0	1	2570
LDDT8	RELOCATABLE	28 MAR 72	23:17:44	52	3	20				2592
LDDT9	FOR SYMB	28 MAR 72	23:17:46	53		22	5	0	1	2615
LDDT9	RELOCATABLE	28 MAR 72	23:17:48	54	3	20				2637
LDDT11	FOR SYMB	28 MAR 72	23:17:49	55		26	5	0	1	2660
LDDT11	RELOCATABLE	28 MAR 72	23:17:51	56	3	19				2686
TYPE11	FOR SYMB	28 MAR 72	23:17:52	57		31	5	0	1	2708
TYPE11	RELOCATABLE	28 MAR 72	23:17:55	58	2	29				2739
T11SBR	FOR SYMB	28 MAR 72	23:17:55	59		11	5	0	1	2770
T11SBR	RELOCATABLE	28 MAR 72	23:17:57	60	2	11				2781
LDDT14	FOR SYMB	28 MAR 72	23:17:58	61		25	5	0	1	2794
LDDT14	RELOCATABLE	28 MAR 72	23:18:00	62	3	19				2819
TYPE14	FOR SYMB	28 MAR 72	23:18:00	63		3	5	0	1	2841
TYPE14	RELOCATABLE	28 MAR 72	23:18:01	64	1	2				2844
LDDT15	FOR SYMB	28 MAR 72	23:18:03	65		26	5	0	1	2847
LDDT15	RELOCATABLE	28 MAR 72	23:18:04	66	3	21				2873
TYPE15	FOR SYMB	28 MAR 72	23:18:05	67		3	5	0	1	2897
TYPE15	RELOCATABLE	28 MAR 72	23:18:06	68	1	2				2900
T14155	FOR SYMB	28 MAR 72	23:18:07	69		9	5	0	1	2903
T14155	RELOCATABLE	28 MAR 72	23:18:08	70	2	10				2912
TP1415	FOR SYMB	28 MAR 72	23:18:09	71		12	5	0	1	2924
TP1415	RELOCATABLE	28 MAR 72	23:18:11	72	2	20				2943
LDDT20	FOR SYMB	28 MAR 72	23:18:12	73		19	5	0	1	2965
LDDT20	RELOCATABLE	28 MAR 72	23:18:13	74	2	14				2984
TYPE20	FOR SYMB	28 MAR 72	23:18:14	75		13	5	0	1	3000
TYPE20	RELOCATABLE	28 MAR 72	23:18:15	76	2	10				3013
LDDT21	FOR SYMB	28 MAR 72	23:18:16	77		17	5	0	1	3025
LDDT21	RELOCATABLE	28 MAR 72	23:18:18	78	2	12				3042
TYPE21	FOR SYMB	28 MAR 72	23:18:19	79		5	5	0	1	3056
TYPE21	RELOCATABLE	28 MAR 72	23:18:19	80	1	3				3061
LDDT22	FOR SYMB	28 MAR 72	23:18:21	81		17	5	0	1	3065
LDDT22	RELOCATABLE	28 MAR 72	23:18:22	82	2	12				3082
TYPE22	FOR SYMB	28 MAR 72	23:18:22	83		5	5	0	1	3096
TYPE22	RELOCATABLE	28 MAR 72	23:18:24	84	1	4				3101
LDDT24	FOR SYMB	28 MAR 72	23:18:25	85		17	5	0	1	3106
LDDT24	RELOCATABLE	28 MAR 72	23:18:26	86	2	12				3123
TYPE24	FOR SYMB	28 MAR 72	23:18:27	87		5	5	0	1	3137
TYPE24	RELOCATABLE	28 MAR 72	23:18:28	88	1	4				3142
LDDT25	FOR SYMB	28 MAR 72	23:18:29	89		17	5	0	1	3147
LDDT25	RELOCATABLE	28 MAR 72	23:18:30	90	2	12				3164
TYPE25	FOR SYMB	28 MAR 72	23:18:31	91		5	5	0	1	3178
TYPE25	RELOCATABLE	28 MAR 72	23:18:32	92	1	4				3183
LDDT26	FOR SYMB	28 MAR 72	23:18:33	93		19	5	0	1	3188
LDDT26	RELOCATABLE	28 MAR 72	23:18:34	94	2	14				3207
TYPE26	FOR SYMB	28 MAR 72	23:18:35	95		14	5	0	1	3223
TYPE26	RELOCATABLE	28 MAR 72	23:18:37	96	2	13				3237
AIDOD	FOR SYMB	28 MAR 72	23:18:37	97		12	5	0	1	3252
AIDOD	RELOCATABLE	28 MAR 72	23:18:39	98	1	8				3264
LA2BY2	FOR SYMB	28 MAR 72	23:18:39	99		4	5	0	1	3273
LA2BY2	RELOCATABLE	28 MAR 72	23:18:40	100	1	2				3277

Figure E.2. (Continued).

LZ2BY2	FOR SYMB	28 MAR 72	23:18:40	101		4	5	0	1	3280
LZ2HY2	RELOCATABLE	28 MAR 72	23:18:42	102	1	2				3284
LZ3BY3	FOR SYMB	28 MAR 72	23:18:42	103		4	5	0	1	3287
LZ3BY3	RELOCATABLE	28 MAR 72	23:18:43	104	1	2				3291
LY2BY2	FOR SYMB	28 MAR 72	23:18:44	105		4	5	0	1	3294
LY2BY2	RELOCATABLE	28 MAR 72	23:18:45	106	1	2				3298
LY3BY3	FOR SYMB	28 MAR 72	23:18:46	107		4	5	0	1	3301
LY3BY3	RELOCATABLE	28 MAR 72	23:18:47	108	1	2				3305
LDDRIM	FOR SYMB	28 MAR 72	23:18:48	109		5	5	0	1	3308
LDDRIM	RELOCATABLE	28 MAR 72	23:18:49	110	1	4				3313
LDSB11	FOR SYMB	28 MAR 72	23:18:49	111		7	5	0	1	3318
LDSB11	RELOCATABLE	28 MAR 72	23:18:51	112	1	3				3325
LS1415	FOR SYMB	28 MAR 72	23:18:51	113		6	5	0	1	3329
LS1415	RELOCATABLE	28 MAR 72	23:18:52	114	1	3				3335
FNDTMS	FOR SYMB	28 MAR 72	23:18:53	115		9	5	0	1	3339
FNDTMS	RELOCATABLE	28 MAR 72	23:18:54	116	2	5				3348
FNDTL	FOR SYMB	28 MAR 72	23:18:55	117		13	5	0	1	3355
FNDTL	RELOCATABLE	28 MAR 72	23:18:56	118	2	9				3368
MTRMOV	FOR SYMB	28 MAR 72	23:18:57	119		4	5	0	1	3379
MTRMOV	RELOCATABLE	28 MAR 72	23:18:58	120	1	3				3383
MTRMUL	FOR SYMB	28 MAR 72	23:18:59	121		12	5	0	1	3387
MTRMUL	RELOCATABLE	28 MAR 72	23:19:00	122	1	11				3399
DLETRC	FOR SYMB	28 MAR 72	23:19:01	123		11	5	0	1	3411
DLETRC	RELOCATABLE	28 MAR 72	23:19:03	124	1	7				3422
LDIMTR	FOR SYMB	28 MAR 72	23:19:03	125		4	5	0	1	3430
LDIMTR	RELOCATABLE	28 MAR 72	23:19:04	126	1	4				3434
DECOM8	FOR SYMB	28 MAR 72	23:19:06	127		45	5	0	1	3439
DECOM8	RELOCATABLE	28 MAR 72	23:19:10	128	2	55				3484
ATOZ	FOR SYMB	28 MAR 72	23:19:10	129		10	5	0	1	3541
ATOZ	RELOCATABLE	28 MAR 72	23:19:12	130	2	9				3551
ZTOA	FOR SYMB	28 MAR 72	23:19:13	131		10	5	0	1	3562
ZTOA	RELOCATABLE	28 MAR 72	23:19:15	132	2	9				3572
ATOY	FOR SYMB	28 MAR 72	23:19:16	133		9	5	0	1	3583
ATOY	RELOCATABLE	28 MAR 72	23:19:17	134	2	11				3592
YTOA	FOR SYMB	28 MAR 72	23:19:18	135		9	5	0	1	3605
YTOA	RELOCATABLE	28 MAR 72	23:19:19	136	2	11				3614
DACMUL	FOR SYMB	28 MAR 72	23:19:20	137		3	5	0	1	3627
DACMUL	RELOCATABLE	28 MAR 72	23:19:21	138	1	2				3630
DCMMUL	FOR SYMB	28 MAR 72	23:19:22	139		3	5	0	1	3633
DCMMUL	RELOCATABLE	28 MAR 72	23:19:23	140	1	2				3636
DCMDIV	FOR SYMB	28 MAR 72	23:19:24	141		3	5	0	1	3639
DCMDIV	RELOCATABLE	28 MAR 72	23:19:25	142	1	3				3642
DCRCIP	FOR SYMB	28 MAR 72	23:19:25	143		3	5	0	1	3646
DCRCIP	RELOCATABLE	28 MAR 72	23:19:27	144	1	2				3649
DCSQRT	FOR SYMB	28 MAR 72	23:19:28	145		10	5	0	1	3652
DCSQRT	RELOCATABLE	28 MAR 72	23:19:29	146	1	9				3662
DCANG1	FOR SYMB	28 MAR 72	23:19:30	147		8	5	0	1	3672
DCANG1	RELOCATABLE	28 MAR 72	23:19:31	148	1	6				3680
DCACSH	FOR SYMB	28 MAR 72	23:19:32	149		5	5	0	1	3687
DCACSH	RELOCATABLE	28 MAR 72	23:19:33	150	1	4				3692
DSHCH	FOR SYMB	28 MAR 72	23:19:34	151		4	5	0	1	3697
DSHCH	RELOCATABLE	28 MAR 72	23:19:35	152	1	3				3701
DCSNCS	FOR SYMB	28 MAR 72	23:19:36	153		5	5	0	1	3705
DCSNCS	RELOCATABLE	28 MAR 72	23:19:37	154	1	3				3710
DCSHCH	FOR SYMB	28 MAR 72	23:19:37	155		5	5	0	1	3714
DCSHCH	RELOCATABLE	28 MAR 72	23:19:39	156	1	3				3719
PRTMTR	FOR SYMB	28 MAR 72	23:19:40	157		5	5	0	1	3723

Figure E.2. (Continued).

SEADUCER RUN 80006 FOR TP-228 APPENDIX E										DATE 102072	PAGE 7
PRTMTR	RELOCATABLE	28 MAR 72	23:19:41	158	1	5				3728	
PRIMBN	FOR SYMB	28 MAR 72	23:19:42	159		5	5	0	1	3734	
PRTMBN	RELOCATABLE	28 MAR 72	23:19:43	160	1	5				3739	
PRMARI	FOR SYMB	28 MAR 72	23:19:43	161		8	5	0	1	3745	
PRMARI	RELOCATABLE	28 MAR 72	23:19:45	162	2	6				3753	
HEAD24	FOR SYMB	28 MAR 72	23:19:45	163		6	5	0	1	3761	
HEAD24	RELOCATABLE	28 MAR 72	23:19:47	164	1	6				3767	
PAGE	FOR SYMB	28 MAR 72	23:19:48	165		1	5	0	1	3774	
PAGE	RELOCATABLE	28 MAR 72	23:19:49	166	1	2				3775	
STRLIN	FOR SYMB	28 MAR 72	23:19:49	167		2	5	0	1	3778	
STRLIN	RELOCATABLE	28 MAR 72	23:19:51	168	1	2				3780	
SKPLIN	FOR SYMB	28 MAR 72	23:19:51	169		2	5	0	1	3783	
SKPLIN	RELOCATABLE	28 MAR 72	23:19:52	170	1	2				3785	
PRPTBL	FOR SYMB	28 MAR 72	23:19:53	171		7	5	0	1	3788	
PRPTBL	RELOCATABLE	28 MAR 72	23:19:54	172	1	5				3795	
PRCTLG	FOR SYMB	28 MAR 72	23:19:55	173		6	5	0	1	3801	
PRCTLG	RELOCATABLE	28 MAR 72	23:19:55	174	2	5				3807	
UNPACK	FOR SYMB	28 MAR 72	23:19:57	175		26	5	0	1	3814	
UNPACK	RELOCATABLE	28 MAR 72	23:19:59	176	1	22				3840	
BLKDTA	FOR SYMB	28 MAR 72	23:20:00	177		15	5	0	1	3863	
BLKDTA	RELOCATABLE	28 MAR 72	23:20:00	178	4	3				3878	
TIME	FOR SYMB	28 MAR 72	23:20:01	179		5	5	0	1	3885	
TIME	RELOCATABLE	28 MAR 72	23:20:02	180	1	3				3890	
Z1TOZ2	FOR SYMB	28 MAR 72	23:20:03	181		8	5	0	1	3894	
Z1TOZ2	RELOCATABLE	28 MAR 72	23:20:04	182	1	6				3902	
DCPCT2	FOR SYMB	28 MAR 72	23:20:05	183		9	5	0	1	3909	
DCPCT2	RELOCATABLE	28 MAR 72	23:20:06	184	1	7				3918	
FNDKRC	FOR SYMB	28 MAR 72	23:20:07	185		26	5	0	1	3926	
FNDKRC	RELOCATABLE	28 MAR 72	23:20:09	186	2	20				3952	
SRCHBC	FOR SYMB	28 MAR 72	23:20:12	187		101	5	0	1	3974	
SRCHBC	RELOCATABLE	28 MAR 72	23:20:16	188	4	76				4075	
MINCHK	FOR SYMB	28 MAR 72	23:20:16	189		3	5	0	1	4155	
MINCHK	RELOCATABLE	28 MAR 72	23:20:18	190	1	2				4158	
MAXCHK	FOR SYMB	28 MAR 72	23:20:18	191		3	5	0	1	4161	
MAXCHK	RELOCATABLE	28 MAR 72	23:20:19	192	1	2				4164	
CMPZS	FOR SYMB	28 MAR 72	23:20:19	193		5	5	0	1	4167	
CMPZS	RELOCATABLE	28 MAR 72	23:20:21	194	2	3				4172	
PREPZV	FOR SYMB	28 MAR 72	23:20:22	195		16	5	0	1	4177	
PREPZV	RELOCATABLE	28 MAR 72	23:20:23	196	2	19				4193	
FNDFZV	FOR SYMB	28 MAR 72	23:20:24	197		7	5	0	1	4213	
FNDFZV	RELOCATABLE	28 MAR 72	23:20:25	198	2	5				4220	
LDZRVR	FOR SYMB	28 MAR 72	23:20:25	199		5	5	0	1	4227	
LDZRVR	RELOCATABLE	28 MAR 72	23:20:27	200	2	3				4232	
SRMIDB	FOR SYMB	28 MAR 72	23:20:29	201		57	5	0	1	4237	
SRMIDB	RELOCATABLE	28 MAR 72	23:20:32	202	4	50				4294	
LDAM2S	FOR SYMB	28 MAR 72	23:20:33	203		19	5	0	1	4348	
LDAM2S	RELOCATABLE	28 MAR 72	23:20:34	204	3	15				4367	
CMPGAM	FOR SYMB	28 MAR 72	23:20:36	205		16	5	0	1	4385	
CMPGAM	RELOCATABLE	28 MAR 72	23:20:37	206	2	14				4401	
FSRCH	FOR SYMB	29 MAR 72	23:20:41	207		142	5	0	1	4417	
FSRCH	RELOCATABLE	28 MAR 72	23:20:48	208	5	123				4559	
RLIMMG	FOR SYMB	28 MAR 72	23:20:48	209		10	5	0	1	4687	
RLIMMG	RELOCATABLE	28 MAR 72	23:20:49	210	2	6				4697	
FMFN	FOR SYMB	28 MAR 72	23:20:50	211		6	5	0	1	4705	
FMFN	RELOCATABLE	28 MAR 72	23:20:51	212	2	5				4711	
POLEO	FOR SYMB	29 MAR 72	23:20:52	213		14	5	0	1	4718	
POLEO	RELOCATABLE	28 MAR 72	23:20:54	214	1	13				4732	

Figure E.2. (Continued).

FRBFIT	FOR SYMB	28 MAR 72	23:20:54	215		9	5	0	1	4746
PRBFIT	RELOCATABLE	28 MAR 72	23:20:55	216	1	7				4755
FNDPRM	FOR SYMB	28 MAR 72	23:20:57	217		40	5	0	1	4763
FNDPRM	RELOCATABLE	28 MAR 72	23:21:00	218	4	29				4803
FNDFDP	FOR SYMB	28 MAR 72	23:21:00	219		8	5	0	1	4836
FNDFDP	RELOCATABLE	28 MAR 72	23:21:01	220	2	3				4844
LDBCOL	FOR SYMB	28 MAR 72	23:21:02	221		6	5	0	1	4849
LDBCOL	RELOCATABLE	28 MAR 72	23:21:03	222	2	4				4855
PRTPRM	FOR SYMB	28 MAR 72	23:21:04	223		14	5	0	1	4861
PRTPRM	RELOCATABLE	28 MAR 72	23:21:05	224	2	9				4875
CONTRL	FOR SYMB	20 OCT 72	13:36:55	225		17	5	0	1	4886
CONTRL	RELOCATABLE	20 OCT 72	13:37:04	226	2	22				4903

NEXT AVAILABLE LOCATION- 4927

ASSEMBLER PROCEDURE TABLE EMPTY

COBOL PROCEDURE TABLE EMPTY

FORTRAN PROCEDURE TABLE EMPTY

ENTRY POINT TABLE

D NAME	LINK	D NAME	LINK	D NAME	LINK	D NAME	LINK	D NAME	LINK
AIDOD	98	ALOCAT	18	ATOY	134	ATOZ	130	BLDKKL	8
BLDMTR	6	CASCDE	32	CHKSTP	20	CMPGAM	206	CMPZS	194
DACMUL	138	DCACSH	150	DCANG1	148	DCMDIV	142	DCMMUL	140
DCPCT2	134	DCPCIP	144	DCSHCH	156	DCSNCS	154	DCSQRT	146
DECOM6	128	DLETRC	124	DSHCH	152	FMFN	212	FNDFDP	220
FNDFZV	198	FNDKRC	186	FNDLCJ	16	FNDMTR	28	FNDNAM	30
FNLNET	22	FNDPRM	218	FNDTL	118	FNDTMS	116	FORMAIN$	226
FSRCH	208	HEAD24	164	LA2BY2	100	LDAM2S	204	LDBCOL	222
LDDRIM	110	LDDT1	36	LDDT11	56	LDDT14	62	LDDT15	66
LDDT2	40	LDDT20	74	LDDT21	78	LDDT22	82	LDDT24	86
LDDT25	90	LDDT26	94	LDDT4	44	LDDT5	46	LDDT7	48
LDDT8	52	LDDT9	54	LDFREQ	12	LDIMTR	126	LDPORT	4
LDSB11	112	LDZRVR	200	LDCMTR	24	LDCNAM	26	LS1415	114
LY2BY2	106	LY3BY3	108	LZ2BY2	102	LZ3BY3	104	MAXCHK	192
MINCHK	190	MTRMOV	120	MTRMUL	122	PAGE	166	POLEO	214
PRBFIT	216	PRCTLG	174	PREPZV	196	PRMARI	162	PRPTBL	172
PRTMBN	160	PRTMTR	158	PRTPRM	224	RDCPRT	10	RLIMMG	210
SKPLIN	170	SRCHBC	188	SRMIDB	202	STRLIN	168	TIME	180
TP1415	72	TYPCAL	34	TYPE1	38	TYPE11	58	TYPE14	64
TYPE15	68	TYPE2	42	TYPE20	76	TYPE21	80	TYPE22	84
TYPE24	88	TYPE25	92	TYPE26	96	TYPE7	50	T11SBR	60
T1415S	70	UNPACK	176	UPPTBL	14	YTOA	136	ZTOA	132
Z11022	182								

Figure E.2. (Continued).

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SEADUCER RUN 80006 FOR TP-22B APPENDIX E                                    DATE 102072        PAGE    9

@MAP,XIB     SYMRUN,ABSRUN
MAP 0022-10/20-13:37 -(,0)

     1.        IN CONTRL

     2.        IN BLKDTA



ADDRESS LIMITS     001000 031614     040000 056710
STARTING ADDRESS  031262

WORDS DECIMAL       12685 IBANK        7625 DBANK


                SEGMENT MAIN              001000 031614      040000 056710

NBDCV$/FOR57                1    001000 001133    2   040000 040037
NFTV$/FOR                   1    001134 001156
NCNVT$/FOR57                1    001157 001411    2   040040 040127
NIOER$/FOR57                1    001412 001530    2   040130 040232
NOUI$/FOR57-UNIV            1    001531 002500    2   040233 040263
NFMT$/FOR57                 1    002501 003405    2   040264 040302
NTAB$/FOR                                         2   040303 040341
ERU$/57
DEXP$/FOR54                 1    003406 003554    2   040342 040375
DLOG$/FOR54                 1    003555 003675    2   040376 040502
DSINCOS$/FOR57              1    003676 004037    2   040503 040561
DATAN$/FOR54                1    004040 004166    2   040562 040644
DSQRT$/FOR57                1    004167 004236    2   040645 040663
DLOG10$/FOR54               1    004237 004247    2   040664 040667
NEXP1$/FOR54                1    004250 004303    0   040670 040670
SQRT$/FOR55                 1    004304 004343    2   040671 040702
NERR$/FOR57-NUC             1    004344 004705    2   040703 041057
NSTOP$/NUC                  1    004706 004731    2   041060 041066
NIER$/FOR52                 1    004732 005014    2   041067 041216
NOSYM$/FOR57                1    005015 005247    2   041217 041224
NINTR$/NUC                  1    005250 005304    2   041225 041244
DATE-TIME/NUC-PACK          1    005305 005334    0   041245 041302
T1415S                      1    005335 005577    0   041303 041326
                            3    CS1415           2   BLANK$COMMON
                                                  4   CM1415
DSHCH                       1    005600 005636    0   041327 041343
                                                  2   BLANK$COMMON
LY3BY3                      1    005637 005666    0   041344 041354
                            3    CY3BY3           2   BLANK$COMMON
LDIMTR                      1    005667 005757    0   041355 041400
                                                  2   BLANK$COMMON
CS1415 (COMMON BLOCK)                                 041401 041404
```

Figure E.2. (Continued).

```
TP1415                        1   005760 006524     0   041405 041471
                              3   CS1415                2   BLANK$COMMON
                              5   CM1415                4   BASIC8
                                                        6   CZ3BY3
UCSHCH                        1   006525 006604     0   041472 041510
                                                        2   BLANK$COMMON
UCACSH                        1   006605 006676     0   041511 041533
                                                        2   BLANK$COMMON
LZ3BY3                        1   006677 006726     0   041534 041544
                              3   CZ3BY3                2   BLANK$COMMON
ZTOA                          1   006727 007153     0   041545 041603
                              3   CA2BY2                2   BLANK$COMMON
                                                        4   CZ2BY2
UCSNCS                        1   007154 007236     0   041604 041622
                                                        2   BLANK$COMMON
LY2BY2                        1   007237 007266     0   041623 041633
                              3   CY2BY2                2   BLANK$COMMON
LZ2BY2                        1   007267 007316     0   041634 041644
                              3   CZ2BY2                2   BLANK$COMMON
LA2BY2                        1   007317 007346     0   041645 041655
                              3   CA2BY2                2   BLANK$COMMON
COMN26 (COMMON BLOCK)                                       041656 041671
CY3BY3 (COMMON BLOCK)                                       041672 041713
TYPE26                        1   007347 007714     0   041714 041755
                              3   BASIC8                2   BLANK$COMMON
                              5   COMN26                4   CY3BY3
TYPE25                        1   007715 007776     0   041756 041775
                              3   BASIC8                2   BLANK$COMMON
TYPE24                        1   007777 010076     0   041776 042015
                              3   BASIC8                2   BLANK$COMMON
TYPE22                        1   010077 010175     0   042016 042035
                              3   BASIC8                2   BLANK$COMMON
TYPE21                        1   010176 010256     0   042036 042055
                              3   BASIC8                2   BLANK$COMMON
TYPE20                        1   010257 010512     0   042056 042143
                              3   BASIC8                2   BLANK$COMMON
                                                        4   CA2BY2
CMN15C (COMMON BLOCK)                                       042144 042145
TYPE15                        1   010513 010537     0   042146 042152
                              3   CMN15C                2   BLANK$COMMON
TYPE14                        1   010540 010564     0   042153 042157
                                                        2   BLANK$COMMON
CZ3BY3 (COMMON BLOCK)                                       042160 042201
TYPE11                        1   010565 011601     0   042202 042272
                              3   BASIC8                2   BLANK$COMMON
                              5   CZ3BY3                4   COMN11
TYPE7                         1   011602 012434     0   042273 042365
                              3   BASIC8                2   BLANK$COMMON
TYPE2                         1   012435 012772     0   042366 042506
                              3   BASIC8                2   BLANK$COMMON
                                                        4   CA2BY2
TYPE1                         1   012773 013207     0   042507 042600
                              3   BASIC8                2   BLANK$COMMON
                                                        4   CA2BY2
CY2BY2 (COMMON BLOCK)                                       042601 042610
ATOY                          1   013210 013515     0   042611 042640
                              3   CA2BY2                2   BLANK$COMMON
```

Figure E.2. (Continued).

			4	CY2BY2
CZ2BY2 (COMMON BLOCK)				042641 042650
CA2BY2 (COMMON BLOCK)				042651 042660
ATOZ	1	013516 013742	0	042661 042717
	3	CA2BY2	2	BLANK$COMMON
			4	CZ2BY2
MTRMOV	1	013743 014011	0	042720 042735
			2	BLANK$COMMON
MTRMUL	1	014012 014262	0	042736 043033
			2	BLANK$COMMON
TYPCAL	1	014263 014565	0	043034 043060
	3	CATALG	2	BLANK$COMMON
CASCDE	1	014566 015020	0	043061 043103
	3	CATALG	2	BLANK$COMMON
			4	CFLGAZ
FNDLCJ	1	015021 015320	0	043104 043132
	3	PRTTBL	2	BLANK$COMMON
			4	CATALG
FNDMET	1	015321 015471	0	043133 043155
	3	PRTTBL	2	BLANK$COMMON
DACMUL	1	015472 015532	0	043156 043164
			2	BLANK$COMMON
DCANG1	1	015533 015671	0	043165 043207
			2	BLANK$COMMON
RDCPRT	1	015672 016710	0	043210 043331
	3	CATALG	2	BLANK$COMMON
			4	CNMRDC
BLDKKL	1	016711 017322	0	043332 043416
	3	PRTTBL	2	BLANK$COMMON
	5	CNMRDC	4	CATALG
	7	CMAGIC	6	CPRT1N
			8	CFLGAZ
PRBFIT	1	017323 017465	0	043417 043462
	3	CPRBFT	2	BLANK$COMMON
POLEO	1	017466 020030	0	043463 043615
			2	BLANK$COMMON
PRMARI	1	020031 020136	0	043616 043655
	3	BASIC6	2	BLANK$COMMON
BLDMTR	1	020137 020415	0	043656 043707
	3	PRTTBL	2	BLANK$COMMON
	5	CPRT1N	4	CATALG
	7	CMAGIC	6	CNMRDC
			8	CBLD
LDFREQ	1	020416 020446	0	043710 043723
	3	BASIC8	2	BLANK$COMMON
			4	PRTOFF
FMFN	1	020447 020567	0	043724 043743
	3	CFMNPR	2	BLANK$COMMON
			4	CMNFMN
RLIMMG	1	020570 020703	0	043744 043770
	3	CFMNPR	2	BLANK$COMMON
			4	PRTOFF
DCMMUL	1	020704 020740	0	043771 043777
			2	BLANK$COMMON
DCMDIV	1	020741 021006	0	044000 044012
			2	BLANK$COMMON
DCRCIP	1	021007 021041	0	044013 044021

Figure E.2. (Continued).

				2	BLANK$COMMON
DCSQRT	1	021042 021270		0	044022 044056
				2	BLANK$COMMON
HEAD24	1	021271 021413		0	044057 044100
	3	CPTWRD		2	BLANK$COMMON
PRIPRM	1	021414 021551		0	044101 044221
	3	CFNDPR		2	BLANK$COMMON
				4	CNAMFP
VALDET (COMMON BLOCK)					044222 044225
DECOMB	1	021552 023513		0	044226 044452
	3	VALDET		2	BLANK$COMMON
	5	DCMSOL		4	DECOND
LDBCOL	1	023514 023606		0	044453 044501
	3	CFNDPR		2	BLANK$COMMON
				4	CMTRFP
FNDFDP	1	023607 023661		0	044502 044530
	3	CFNDPR		2	BLANK$COMMON
	5	CFMWPR		4	BASICB
CM1415 (COMMON BLOCK)					044531 044562
LS1415	1	023662 023730		0	044563 044575
	3	CM1415		2	BLANK$COMMON
				4	CEGSFP
FNDMTR	1	023731 024006		0	044576 044606
	3	CATALG		2	BLANK$COMMON
LOCMTR	1	024007 024063		0	044607 044620
	3	CATALG		2	BLANK$COMMON
T11SBR	1	024064 024360		0	044621 044655
	3	COMN11		2	BLANK$COMMON
LDDRIM	1	024361 024443		0	044656 044666
	3	DTASUB		2	BLANK$COMMON
LDSB11	1	024444 024512		0	044667 044701
	3	COMN11		2	BLANK$COMMON
				4	CEGSFP
CHKSTR	1	024513 024543		0	044702 044717
	3	CTATOT		2	BLANK$COMMON
SKPLIN	1	024544 024576		0	044720 044727
				2	BLANK$COMMON
ALOCAT	1	024577 024660		0	044730 044754
	3	CATALG		2	BLANK$COMMON
				4	DTASUB
FNDNAM	1	024661 024724		0	044755 044765
	3	CATALG		2	BLANK$COMMON
AIDOD	1	024725 025116		0	044766 045010
				2	BLANK$COMMON
UPPTBL	1	025117 025310		0	045011 045033
	3	PRTTBL		2	BLANK$COMMON
				4	CUPTBL
UNPACK	1	025311 026074		0	045034 045141
	3	CPTWRD		2	BLANK$COMMON
PRCTLG	1	026075 026151		0	045142 045217
	3	CATALG		2	BLANK$COMMON
				4	DTASUB
PRPTBL	1	026152 026230		0	045220 045276
	3	PRTTBL		2	BLANK$COMMON
CNAMFP (COMMON BLOCK)					045277 045301
CMTRFP (COMMON BLOCK)					045302 045302
CEGSFP (COMMON BLOCK)					045303 045310

Figure E.2. (Continued).

```
DECOND (COMMON BLOCK)                                         045311 045312
DCMSOL (COMMON BLOCK)                                         045313 045730
CFNDPR (COMMON BLOCK)                                         045731 046072
FNDPRM                    1   026231 027161         0         046073 046215
                          3   CFNDPR                2         BLANK$COMMON
                          5   DECOND                4         DCMSOL
                          7   CATALG                6         BASICB
                          9   CESSFP                8         CMNFMN
                         11   CNAMFP               10         CMTRFP
TIME                      1   027162 027210         0         046216 046242
                                                    2         BLANK$COMMON
COMN11 (COMMON BLOCK)                                         046243 046303
LDOT11                    1   027211 027646         0         046304 046464
                          3   CATALG                2         BLANK$COMMON
                          5   COMN11                4         DTASUB
                                                    6         PRTOFF
LDOT2                     1   027647 030307         0         046465 046632
                          3   CATALG                2         BLANK$COMMON
                          5   PRTOFF                4         DTASUB
LDOT1                     1   030310 030704         0         046633 046752
                          3   CATALG                2         BLANK$COMMON
                          5   PRTOFF                4         DTASUB
LDPORT                    1   030705 031227         0         046753 047042
                          3   PRTTBL                2         BLANK$COMMON
                                                    4         CPTWRD
STRLIN                    1   031230 031244         0         047043 047066
                                                    2         BLANK$COMMON
PAGE                      1   031245 031261         0         047067 047074
                                                    2         BLANK$COMMON
CSRHBC (COMMON BLOCK)                                         047075 047075
CMNFMN (COMMON BLOCK)                                         047076 047100
CFMNPR (COMMON BLOCK)                                         047101 047101
FRGMTR (COMMON BLOCK)                                         047102 047102
CSRMTR (COMMON BLOCK)                                         047103 047103
CUPTBL (COMMON BLOCK)                                         047104 047104
CPREET (COMMON BLOCK)                                         047105 047110
CSTACK (COMMON BLOCK)                                         047111 047111
CNMRDC (COMMON BLOCK)                                         047112 047113
CPRTIN (COMMON BLOCK)                                         047114 047115
CMAGIC (COMMON BLOCK)                                         047116 047116
CBLJ (COMMON BLOCK)                                           047117 047117
CFLGAZ (COMMON BLOCK)                                         047120 047120
CPTWRD (COMMON BLOCK)                                         047121 047122
BASICB (COMMON BLOCK)                                         047123 047130
PRTOFF (COMMON BLOCK)                                         047131 047131
DTATOT (COMMON BLOCK)                                         047132 047132
DTASUB (COMMON BLOCK)                                         047133 047133
CATALG (COMMON BLOCK)                                         047134 050430
PRTTBL (COMMON BLOCK)                                         050431 052545
BLANK$COMMON (COMMON BLOCK)                                   052546 056465
CONTRL                    1   031262 031614         0         056466 056710
                          3   BASICB                2         BLANK$COMMON
                                                    4         DTATOT
BLKDTA                    3   PRTTBL                2         BLANK$COMMON
                          5   DTASUB                4         CATALG
                          7   PRTOFF                6         DTATOT
                          9   CPTWRD                6         BASICB
```

Figure E.2. (Continued).

```
SEADUCER RUN 80006 FOR TP-22A APPENDIX E                                   DATE 102072        PAGE    14

                         11    CBLD          10    CFLGAZ
                         13    CPRT1N        12    CMAGIC
                         15    CSTACK        14    CNMPDC
                         17    CUPTBL        16    CPRBFT
                         19    PRGMTR        18    CSRMTR
                         21    CMNEMN        20    CEMNPR
                                             22    CSRHBC

SYS$*RLIB$. LEVEL 57
END OF COLLECTION - TIME 4.411 SECONDS
```

Figure E.2. (Continued).

SEADUCER RUN 80006 FOR TM-228 APPENDIX E DATE 102072 PAGE 15

XGT ABSRUN

Figure E.2. (Continued).

```
SEADUCER RUN 80006 FOR TP-228 APPENDIX E                                          DATE 102072        PAGE   16

***************************************************************************************
SEADUCER RUN 80006 (LIKE MOD 7 RUN 70443) MAY 14,1970
TO CHECKOUT FIND PARAMETERS

* * * * * JD  8 NETWORK TABLE

S  1D8D, 3C3A,$
S  2D8D, 2T2B,$
S  3D8D, 1Q2Q, 1V2V,$
S  4D8D, 1C3A,   -+2Q2Q,$
S  5D8D, 1P2P, -+2L2L, -+2C3A,$
S  6D8D, 2P2P, -+1T2B,$
S  7D8D, 1L2L, 1T2A, -+2V2V,$
S  8D8D, 2T2A,$

TYPE 1         RHO        AREA          ID       OD        LENGTH
T2A1$          7683.51    .766601-03    .000000  .000000   .003556
               C REAL     C IMAG        C MULT                          MASS
               5043.80    .000000       .000000                         .02095

TYPE 2         RHO        A1            ID1      OD1
T2A2$          7683.51    .766601-03    .000000  .000000
                          A2            ID2      OD2       LENGTH
                          .467602-03    .000000  .000000   .004064
               C REAL     C IMAG        C MULT                          MASS
               5043.80    .000000       .000000                         .01900

TYPE 1         RHO        AREA          ID       OD        LENGTH
T2A3$          7683.51    .467602-03    .000000  .000000   .010465
               C REAL     C IMAG        C MULT                          MASS
               5043.80    .000000       .000000                         .03760

TYPE 1         RHO        AREA          ID       OD        LENGTH
V2V1$          7696.86    .101971-02    .000000  .000000   .003150
               C REAL     C IMAG        C MULT                          MASS
               5116.00    .000000       .000000                         .02472

TYPE 1         RHO        AREA          ID       OD        LENGTH
Q2Q1$          7822.86    .427004-02    .000000  .000000   .031763
               C REAL     C IMAG        C MULT                          MASS
               5116.00    .000000       .000000                         1.06100

TYPE 1         RHO        AREA          ID       OD        LENGTH
P2P1$          7919.77    .455735-02    .000000  .000000   .031763
               C REAL     C IMAG        C MULT                          MASS
               5116.00    .000000       .000000                         1.14642

TYPE 1         RHO        AREA          ID       OD        LENGTH
T2B1$          7807.65    .255000-03    .000000  .000000   .003734
               C REAL     C IMAG        C MULT                          MASS
               5043.80    .000000       .000000                         .00743
```

Figure E.2. (Continued).

```
SEADUCER RUN 80006 FOR TP-228 APPENDIX E                                      DATE 102072      PAGE   17

TYPE 1      RHO        AREA         ID      OD      LENGTH
L2L1$       7807.65    .255000-03   .000000 .000000 .010490
            C REAL     C IMAG       C MULT                   MASS
            5043.80    .000000      .000000                  .02039

TYPE 1      RHO        AREA         ID      OD      LENGTH
L2L2$       7807.65    .285785-03   .000000 .000000 .035179
            C REAL     C IMAG       C MULT                   MASS
            5043.80    .000000      .000000                  .07850

TYPE 1      RHO        AREA         ID      OD      LENGTH
L2L3$       7807.65    .198250-03   .000000 .000000 .329286
            C REAL     C IMAG       C MULT                   MASS
            5043.80    .000000      .000000                  .50969

TYPE 1      RHO        AREA         ID      OD      LENGTH
L2L4$       7807.65    .255000-03   .000000 .000000 .003874
            C REAL     C IMAG       C MULT                   MASS
            5043.80    .000000      .000000                  .00771

TYPE 11     RHO        AREA         ID      OD      LENGTH
C3A$        7555.00    .253355-02   .000000 .000000 .019107
            C REAL     C IMAG       C MULT          N PIECES MASS
            3821.90    .330786+01   .865499-03      18       6.58291

                  REAL                 IMAG                  MULT
       E33T    .1325100000+04      -.5041288100+01      .2295000000-02
       G33     .2205000000-01      -.7834365000-05      .3553000000-03
       S33D    .9001600000-11      -.1568562960-13      .1731000000-02

       K33     .6215604474+00      -.2430839033-03
LAST TIME INTERVAL =    .363 SEC          TOTAL RUN TIME =    .363 SEC
```

Figure E.2. (Continued).

* * * * * SEADUCER FIND PARAMETERS * * * * *

	EXPERIMENT	THEORY	GUESS	ERROR
FLO	.5000000000+03			
FM	.3526000000+04	.3527572090+04	.3493751762+04	.45-03
FN	.4268000000+04	.4271200752+04	.4230159983+04	.75-03
CLO	.2626130002-07	.2625956206-07	.2626501073-07	.74-04
YM	.1300000000+00			
ZM	.7692307644+01	.7712460307+01	.1008811533+02	.26-02
YN	.2429999995-05	.2442311673-05	.2368592649-05	.51-02
CLOM	.1706499999-02	.1704630565-02	.2119534606-02	.11-02

GUESS	REAL	IMAG	MULT
E33T	.1325180000+04	-.3041268100+01	.2295000000-02
G33	.2205000000-01	-.7834265000-05	.3553000000-03
S33D	.9061600000-11	-.1568502960-13	.1731000000-02

THEORY	REAL	IMAG	MULT
E33T	.1322977464+04	-.2361743064+01	.1785172573-02
G33	.2178529666-01	.2951158578-05	-.1354656135-03
S33D	.8868324985-11	-.1624967098-13	.1832349515-02

ITERATION 1 MATRIX CONDITION WAS 1.26

Figure E.2. (Continued).

SEADUCER RUN 80006 FOR TP-22A APPENDIX E   DATE 102072   PAGE 19

* * * * * SEADUCER FIND PARAMETERS * * * * *

	EXPERIMENT	THEORY	GUESS	ERROR
FLO	.5000000000+03			
EM	.3526000000+04	.3525976668+04	.3527572090+04	.66-05
FN	.4268000000+04	.4267928922+04	.4271200752+04	.17-04
CLO	.2626130002-07	.2626130161-07	.2625936206-07	.61-07
YM	.1300000008+00			
ZM	.7692307644+01	.7692299629+01	.7712460307+01	.10-05
YN	.2429999995-05	.2429977740-05	.2442311673-05	.92-05
CLOM	.1706499999-02	.1706496574-02	.1704630565-02	.20-05

GUESS	REAL	IMAG	MULT
E33T	.1322977464+04	-.2361743084+01	.1785172573-02
G33	.2178529666-01	.2951158578-05	-.1354656135-03
S33D	.8868324985-11	-.1624987098-13	.1832349515-02

THEORY	REAL	IMAG	MULT
E33T	.1323056087+04	-.2364381405+01	.1787060601-02
G33	.2178409103-01	.2974214549-05	-.1365314966-03
S33D	.8884305587-11	-.1617550809-13	.1820683443-02

ITERATION 2   MATRIX CONDITION WAS 1.69
FINAL ANSWER
LAST TIME INTERVAL = 18.524 SEC   TOTAL RUN TIME = 18.887 SEC

Figure E.2. (Continued).

* * * * * COMMON PRT TBL * * * * *

N	NET SP	I SIGN C	D	J PORT	N PORTS	NET NA.	NUM APO	NUM NPO	N AHEAD	N BACK	LC J ROW
1	S	1	1	1	8	DD	1	-1	3	0	1
2	S	1	1	3	3	CA	1	3	17	14	609
3	S	1	1	2	8	DD	2	-2	5	1	2
4	S	1	1	2	2	TB	2	5	6	17	461
5	S	1	1	3	8	DD	3	-3	8	3	3
6	S	1	1	1	2	QQ	3	6	10	4	382
7	S	1	1	1	2	VV	3	8	21	10	343
8	S	1	1	4	8	DD	4	-4	11	5	4
9	S	1	1	1	3	CA	4	1	14	0	607
10	S	-1	1	2	2	QQ	4	7	7	6	383
11	S	1	1	5	8	DD	5	-5	15	8	5
12	S	1	1	1	2	PP	5	10	16	21	421
13	S	-1	1	2	2	LL	5	13	20	19	500
14	S	-1	1	2	3	CA	5	2	2	9	608
15	S	1	1	6	8	DD	6	-6	18	11	6
16	S	1	1	2	2	PP	6	11	19	12	422
17	S	-1	1	1	2	TB	6	4	4	2	460
18	S	1	1	7	8	DD	7	-7	22	15	7
19	S	1	1	1	2	LL	7	12	13	16	499
20	S	1	1	1	2	TA	7	14	23	13	257
21	S	-1	1	2	2	VV	7	9	12	7	344
22	S	1	1	8	8	DD	8	-8	0	18	8
23	S	1	1	2	2	TA	8	15	0	20	258

Figure E.2. (Continued).

* * * * * COMMON CATALOG * * * * *

I	NAME	MTR SIZ	I PC	N PC TOT	I TYPE	N OUT STR	LOC
1	DD	8	0	0	0	0	1
2	TA	2	0	3	0	0	257
3	TA	2	1	3	1	7	273
4	TA	2	2	3	2	8	296
5	TA	2	3	3	1	7	320
6	VV	2	0	1	0	0	343
7	VV	2	1	1	1	7	359
8	QQ	2	0	1	0	0	382
9	QQ	2	1	1	1	7	398
10	PP	2	0	1	0	0	421
11	PP	2	1	1	1	7	437
12	TB	2	0	1	0	0	460
13	TB	2	1	1	1	7	476
14	LL	2	0	4	0	0	499
15	LL	2	1	4	1	7	515
16	LL	2	2	4	1	7	538
17	LL	2	3	4	1	7	561
18	LL	2	4	4	1	7	584
19	CA	3	0	0	11	33	607
20	FP	6	0	0	0	0	676
21	DD	1	0	0	0	0	746
22	DD	0	0	0	0	0	752
23	DD	0	0	0	0	0	948

TOTAL DATA CELLS USED IN MASTER STORAGE 975

Figure E.2. (Continued).

```
SEADUCER RUN 8000S FOR TP-22R APPENDIX E                                    DATE 102072        PAGE   22
 LAST TIME INTERVAL =    .260 SEC          TOTAL RUN TIME =  19.155 SEC

#BRKPT   PRINT$

                 RUNID:  M8000E    ACCOUNT: IE0170010000    PROJECT: LME010314522
                   LOAD B8000E 9/4 PRFILE       -1 M8000E
                  M8000E*MSG: SD 2138
                  BREAKPOINT IN THIS RUN
               *M8000E PRTAPE SAVE=2911 [redacted]
               [redacted]
                   LOAD 279     9/7 B           -1 M8000E
                  BREAKPOINT IN THIS RUN
                 TIME: 00:00:26.825    IN: 84     OUT: 0        PAGES:   30
                 WDS XFRD(E2): 5233    I/O REFS: 1739    CORE SEC: 1150
                 INITIATION  TIME:    13:22:43-OCT 20,1972     VERSION:  26.70.158 10
                 TERMINATION TIME:    13:38:16-OCT 20,1972
```

Figure E.2. (Continued).

APPENDIX F

ACTIVE BAND-PASS FILTER ANALYSIS EXAMPLE

An active band-pass filter analysis is obtained by cascading an eighth-order Chebyshev low-pass filter (figures F.1 and F.5) with an eighth-order Chebyshev high-pass filter (figures F.2 and F.5). The high-pass and low-pass filters are each composed of four individual second-order active stages (figure F.3) in cascade. Each stage is modeled using Type 26 Operational Amplifier (figure F.4) in conjunction with Type 21 Series Impedance and Type 22 Parallel Impedance (figure F.5).

The voltage gain of the composite band-pass filter is computed as a function of frequency and is plotted in dB (referenced to unity gain) along with the measured response of the prototype circuit being modeled (figure F.6).

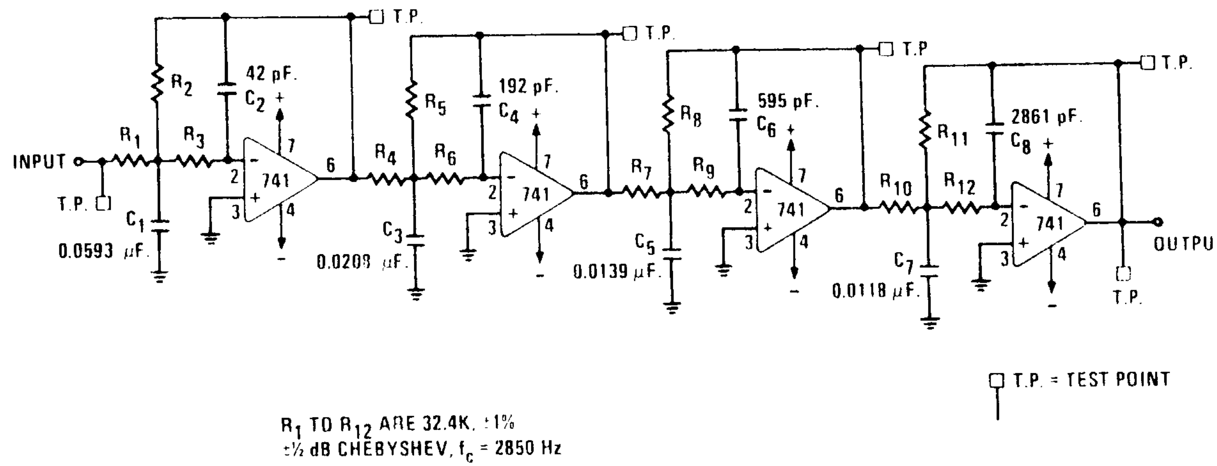
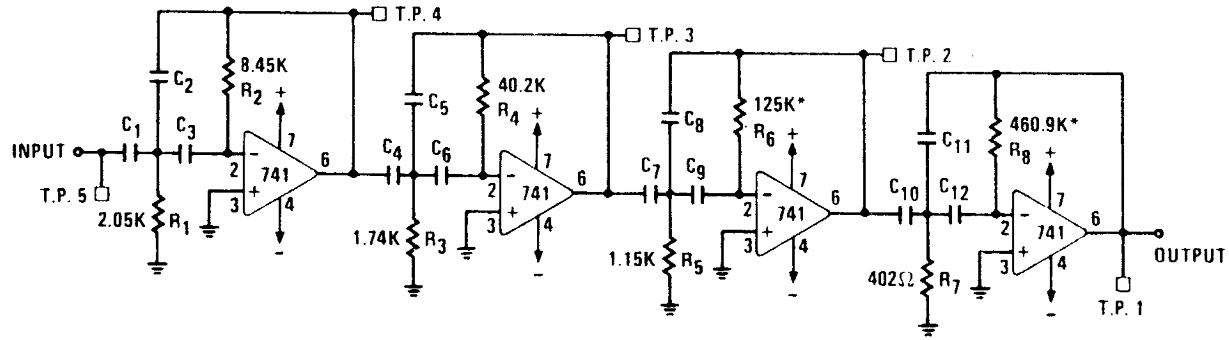


Figure F.1. Low-Pass Filter.

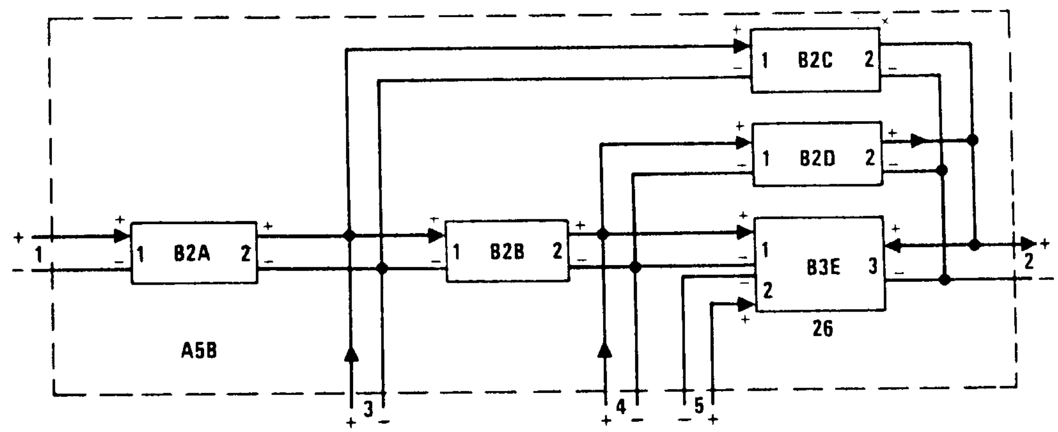


* = EXACT VALUE, OTHERS
ARE TO NEAREST
1% VALUE

T.P. = TEST POINT

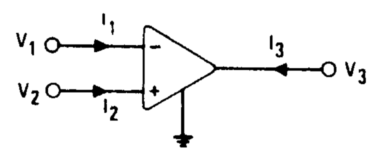
ALL CAPACITORS ARE 5300 pF., ±1%
± ½ dB CHEBYSHEV, f_c = 2150 Hz

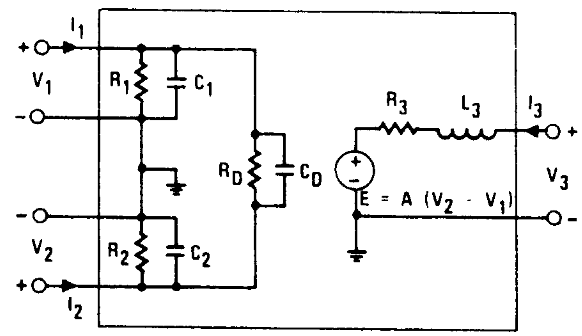
Figure F.2. High-Pass Filter.




```
CALL LD PORT ('P', '1A5B, 1B2A,$')
CALL LD PORT ('P', '2A5B, 2B2C, 2B2D, -+3B3E,$')
CALL LD PORT ('P', '3A5B, -+2B2A, 1B2B, 1B2C,$')
CALL LD PORT ('P', '4A5B, -+2B2B, 1B2D, 1B3E,$')
CALL LD PORT ('P', '5A5B, 2B3E,$')
```

Figure F.3. Individual Second-Order Active Filter Stage Showing Sign Convention Diagram and Corresponding Computer Input.



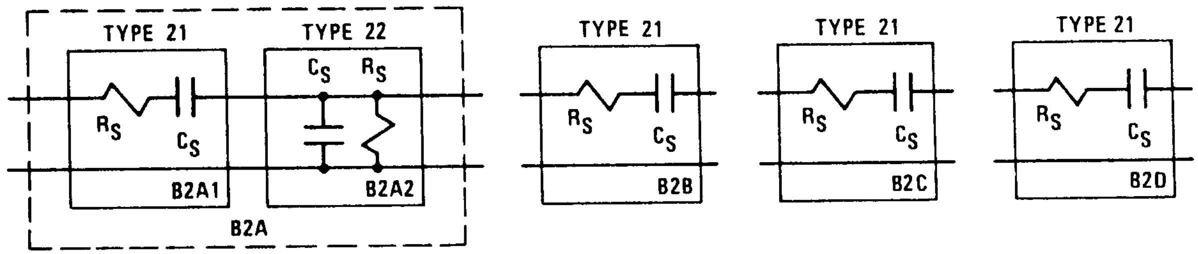


INPUT PARAMETERS

R_1 =	INPUT RESISTANCE (OHMS)	$= 10^6$
C_1 =	INPUT CAPACITANCE (Fd)	$= .7 \times 10^{-12}$
R_2 =	INPUT RESISTANCE (OHMS)	$= 10^{-10}$
C_2 =	INPUT CAPACITANCE (Fd)	$= 10^{-10}$
R_D =	DIFFERENTIAL INPUT RESISTANCE (OHMS)	$= 10^6$
C_D =	DIFFERENTIAL INPUT CAPACITANCE (Fd)	$= .7 \times 10^{-12}$
R_3 =	OUTPUT RESISTANCE (OHMS)	$= 75$
L_3 =	OUTPUT INDUCTANCE (Hy)	$= 0$
A_0 =	DC OPEN LOOP GAIN	$= 70000$
$\omega_1, \omega_2, \omega_3$ =	FIRST THREE POLE FREQUENCIES OF THE OPEN LOOP TRANSFER FUNCTION (RADIANS/SEC)	$= 2\pi \times 10$ $2\pi \times 3 \times 10^6$ $2\pi \times 10^9$

AND: f = FREQUENCY (Hz) = 1000 TO 10000 $\omega = 2\pi f$

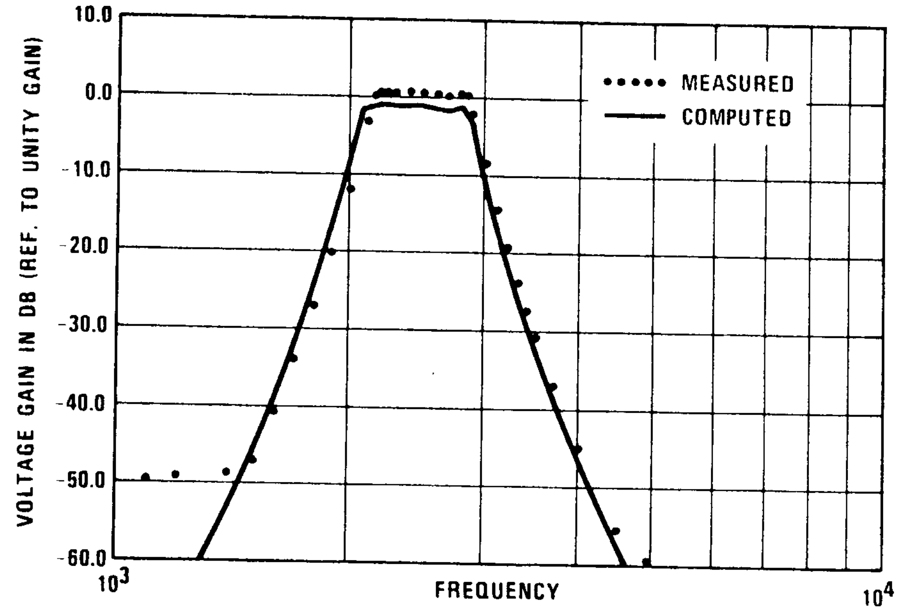
Figure F.4. Type 26: Linear Model Of a Differential Input Operational Amplifier With Active Filter Input Values.



LOW-PASS: R_S = 32.4K FOR B2A1, B2B, B2C, R_S = 0 FOR B2A2, B2D
C_S = C_1, C_3, C_5, C_7 FOR B2A2 FOR STAGES 1-4 RESPECTIVELY
C_S = C_2, C_4, C_6, C_8 FOR B2D FOR STAGES 1-4 RESPECTIVELY
C_S = ∞ FOR B2A1, B2B, B2C

HIGH-PASS: C_S = 5300 pF. FOR B2A1, B2B, B2C, C_S = ∞ FOR B2A2, B2D
R_S = R_1, R_3, R_5, R_7 FOR B2A2 FOR STAGES 1-4 RESPECTIVELY
R_S = R_2, R_4, R_6, R_8 FOR B2D FOR STAGES 1-4 RESPECTIVELY
R_S = 0 FOR B2A1, B2B, B2C

Figure F.5. Series And Parallel Impedance Input For Individual Active Filter Stages.



SEADUCER RUN 80117F MAR 21, 1972
HI PASS – LO PASS CASCADE
W/ 1/2 DB RIPPLE FACTOR, (FLP-2850, FHP-2150)

Figure F.6. Plot of Voltage Gain as a Function of Frequency.

Figure F.7.

Listing and Output of the Control Routine for an Active Band-Pass Filter Analysis.

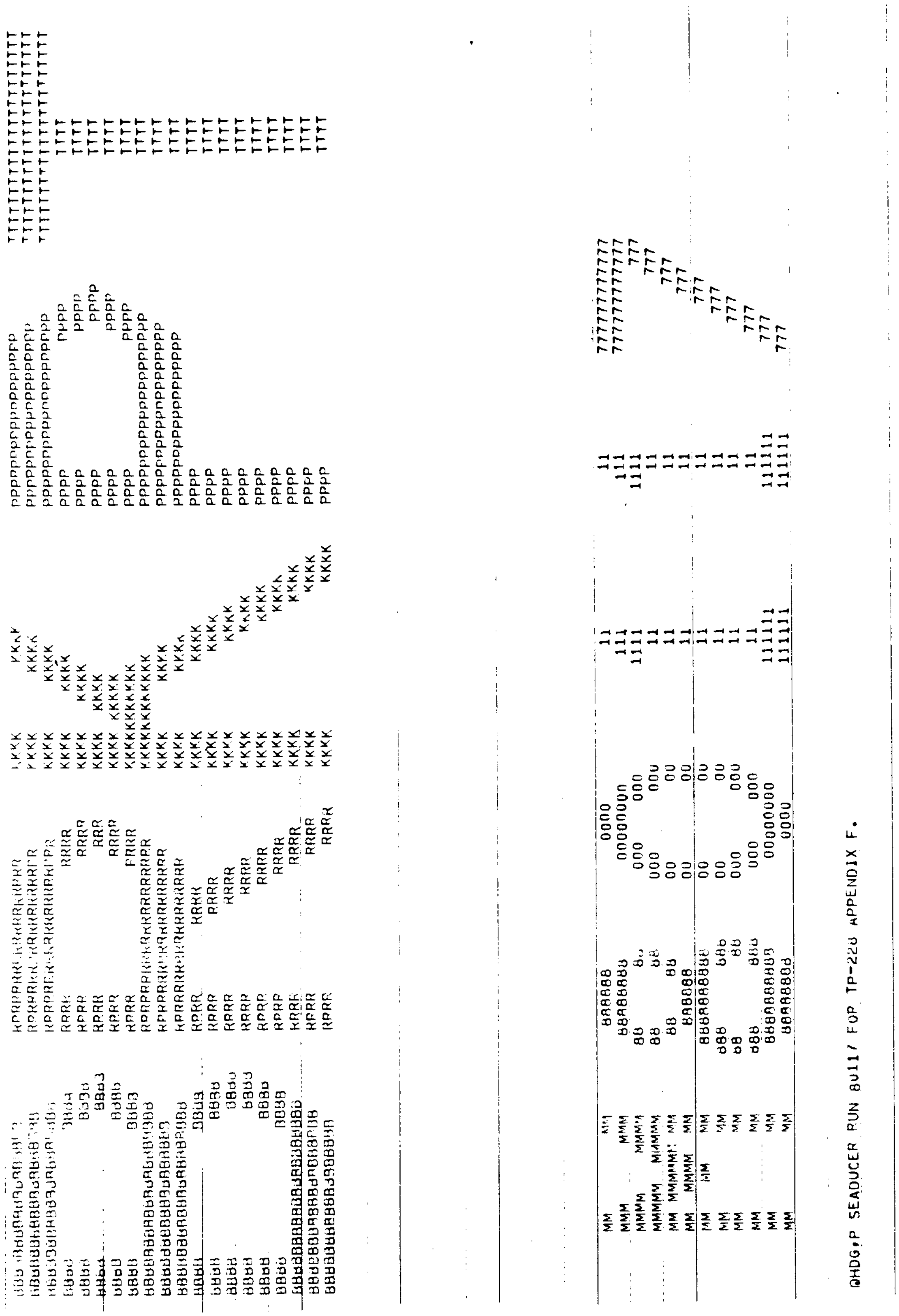


Figure F.7. (Continued).

```
SEADUCER RUN 80117 FOR TR-228 APPENDIX F                                DATE 102072        PAGE     1

@COPIN B.,TPF$.
FURPUR 023A-10/20-15:25
 112 SYM  112 REL


@FREE   B.
```

Figure F.7. (Continued).

```
SEADUCER RUN 80117 FOR TP-228 APPENDIX F                                              DATE 102072      PAGE    2

@FOR,IS     CONTRL,CONTRL
FOR 0010-10/20/72-15:24:00 (,0)

  MAIN PROGRAM

  STORAGE USED: CODE(1) 000720; DATA(0) 000341; BLANK COMMON(2) 003720

   COMMON BLOCKS:

   0003    CATALG 001275
   0004    PPTOFF 000001
   0005    DTATOT 000001

  EXTERNAL REFERENCES (BLOCK, NAME)

   0006    SETCLK
   0007    PAGE
   0010    STRLIN
   0011    LDPURT
   0012    LDDT4
   0013    LDDT26
   0014    LDFREQ
   0015    LDDT21
   0016    LDDT22
   0017    BLDMTP
   0020    FNDNAM
   0021    LOCMTP
   0022    YTOA
   0023    MTRMOV
   0024    DCRCIP
   0025    CASCDE
   0026    DCANG1
   0027    HEAD24
   0030    PRTMTR
   0031    PRPTBL
   0032    PRCTLG
   0033    TIME
   0034    NINTR$
   0035    NPRT$
   0036    NIO2$
   0037    NWDC$
   0040    NEXP1$
   0041    DSQRT
   0042    ALOG10
   0043    NSTOP$

  STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

   0001     000347 10L       0001     000417 15L       0001     000145 160G      0001     000201 173G      0001     000446 20L
   0001     000251 205G      0001     000635 38L       0001     000667 39L       0001     000676 40L       0000     000063 5F
   0000     000240 50F       0001     000502 52L       0001     000524 55L       0000     000255 60F       0000 R 000041 CS
   0000 R 000002 C1         0000 R 000006 C2         0002 D 000000 DATA       0025 D 000000 DCANG1     0000 D 000036 DDF
   0000 D 000000 DIM        0000 D 000052 DRL        0000 I 000030 I          0000 I 000054 IAA2A      0000 I 000050 IAA2B
   0000 I 000045 IA2A       0000 I 000051 IA2AL      0003     001274 ICLOSB    0000 I 000027 IEXPHI     0000 I 000026 IEXPLO
   0000 I 000031 IEXPO      0000 I 000035 IF         0000 I 000044 IFTF       0003     000310 IPC       0003     000620 ITYPF
```

Figure F.7. (Continued).

```
     0000 I 000047 IYA2B      0000 I 000046 IYA5B      0000 I 000034 J          0000 I 000033 JHI        0000 I 000032 JLO
     0000 I 000022 L          0000 I 000043 LL         0003 I 001130 LOC        0021 I 000000 LOCMTR     0000 I 000040 LTOP
     0003   000144 MTRSIZ     0005 I 000000 MXDATA     0003   000000 NAME       0003   000764 NDTSTR     0004 I 000000 NOPRT
     0003   000454 NPCTOT     0000 R 000023 OMEGA1     0000 R 000024 OMEGA2     0000 R 000025 OMEGA3     0000 R 000057 RANG
     0000 R 000056 RDB        0000 R 000060 RDF        0000 R 000062 RIMAG      0000 R 000055 RMAG       0000 R 000061 RREAL
     0000 R 000042 RS         0000 R 000012 R1         0000 R 000016 R2

00101       1*          IMPLICIT DOUBLE PRECISION (D)
00103       2*          COMMON / CATALG / NAME(100), MTR SIZ(100), I PC(100),
00103       3*         1     N PC TOT(100), I TYPE(100), N DT STR(100), LOC(100), I CLG SR
00104       4*          COMMON / PRT OFF / NO PRT
00105       5*          COMMON / DTA TOT / MX DATA
00106       6*          COMMON /          / DATA(1000)
00107       7*          DIMENSION C1(4), C2(4)
00110       8*          DIMENSION R1(4), R2(4)
00111       9*          DATA (C1(L), L=1,4 ) / .0593E-6, .0208E-6, .0139E-6, .0118E-6 /
00113      10*          DATA (C2(L), L=1,4 ) /42.E-12,192.E-12,595.E-12,2861.E-12 /
00115      11*          DATA(R1(L), L=1,4) / 2.05E3, 1.74E3, 1.15E3, 402. /
00117      12*          DATA(R2(L), L=1,4) / 8.45E3, 40.2E3, 125.E3, 460.9E3 /
00121      13*          MX DATA = 1000
00122      14*
00122      15*          CALL SETCLK
00123      16*          CALL PAGE
00124      17*          CALL STR LIN
00125      18*          PRINT 5
00127      19*        5 FORMAT(' SEADUCER RUN 80117F  MAR 21,1972 $'/
00127      20*         /       ' HI PASS - LO PASS CASCADE $'/
00127      21*         /       ' W/ 1/2 DB RIPPLE FACTOR, (FLP=2850, FHP=2150) $'/
00127      22*         /       ' CHARGE TO 16000401 AMPLIFIERS' )
00130      23*
00130      24*          CALL LD PORT( 'P', '1A5B,  1B2A,$' )
00131      25*          CALL LD PORT( 'P', '2A5B,   2B2C,  2B2D,-+3B3E,$' )
00132      26*          CALL LD PORT( 'P', '3A5B, -+2B2A,  1B2B,  1B2C,$' )
00133      27*          CALL LD PORT( 'P', '4A5B, -+2B2B,  1B2D,  1B3E,$' )
00134      28*          CALL LD PORT( 'P', '5A5B,  2B3E,$' )
00135      29*
00135      30*          CALL LD DT 4('A2A1$', 1. )
00136      31*          CALL LD DT 4('A2A2$', 1. )
00137      32*          CALL LD DT 4('A2A3$', 1. )
00140      33*          CALL LD DT 4('A2A4$', 1. )
00141      34*          CALL LD DT 4('A2A5$', 1. )
00142      35*          CALL LD DT 4('A2A6$', 1. )
00143      36*          CALL LD DT 4('A2A7$', 1. )
00144      37*          CALL LD DT 4('A2A8$', 1. )
00145      38*
00145      39*          OMEGA1 = 2.*3.14159 * 10.
00146      40*          OMEGA2 = 2.*3.14159 * 3.E6
00147      41*          OMEGA3 = 2.*3.14159 * 1.E9
00150      42*          CALL LD DT 26('B3E$', 1.E6,.7E-12, 1.E-10,1.E-10, 1.E6,.7E-12,
00150      43*         *                75.,0., 70000., OMEGA1,OMEGA2,OMEGA3)
00151      44*
00151      45*          PUNCH 5
00153      46*          PUNCH 50
00155      47*
```

Figure F.7. (Continued).

```
00155        I EXP LO = 3
00156        I EXP HI = 3
00157        DO 200 I = I EXP LO, I EXP HI
00162        I EXPO = 10**(I-1)
00163        J LO = 1
00164        J HI = 9
00165        IF ( I .EQ. I EXP HI ) JHI = 1
00167        J LO = 10
00170        J HI = 100
00171        J HI = 50
00172        DO 100 J = J LO, J HI
00175        IF = J * I EXPO
00176        DDF = IF
00177        NO PPT = 0
00200        NO PPT = 1
00201        CALL LD FREQ(DDF)
00202
00202        LTOP = 2
00203        LTOP = 5
00204        LTOP = 9
00205        DO 300 L = 1, L TOP
00210        IF ( L .EQ. L TOP ) GO TO 32
00212        IF ( I .EQ. I EXP LO .AND. J .EQ. 1 ) CALL PAGE
00214        NO PRT = 1
00215        IF ( I .EQ. I EXP LO .AND. J .EQ. 1 ) NO PRT = 0
00217        IF ( L .GE. 5 ) GO TO 10
00217     C * * * * * HI PASS
00221        CS = 5300.E-12
00222        CALL LD DT 21('B2A1$', 0., 0., CS )
00223        CALL LD DT 22('B2A2$', R1(L), 0., 1.E30 )
00224        CALL LD DT 21('B2B1$', 0., 0., CS )
00225        CALL LD DT 21('B2C1$', 0., 0., CS )
00226        CALL LD DT 21('B2D1$', R2(L), 0., 1.E30 )
00227        GO TO 15
00230     10 CONTINUE
00230     C * * * * * LO PASS
00231        RS = 32.4E3
00232        LL = L - 4
00233        CALL LD DT 21('B2A1$', RS, 0., 1.E30 )
00234        CALL LD DT 22('B2A2$', 0., 0., C1(LL))
00235        CALL LD DT 21('B2B1$', RS, 0., 1.E30 )
00236        CALL LD DT 21('B2C1$', RS, 0., 1.E30 )
00237        CALL LD DT 21('B2D1$', 0., 0., C2(LL))
00240     15 CONTINUE
00241
00241        CALL BLD MTR('A2B$')
00242        IF ( I FTF .NE. 0 ) GO TO 20
00244        IFTF = 1
00245        CALL FND NAM('AA', I A2A )
00246        IY A5B = LOC MTR('AB', 5)
00247        IY A2B = LOC MTR('AB', 2)
00250        IA A2B = IY A2B + 8
00251     20 CONTINUE
00252        CALL Y TO X(IY A2B, IA A2B)
00253
00253        I A2A L = I A2A + L
00254        CALL MTR MOV(LOC(I A2AL), IA A2B, 2)
```

Figure F.7. (Continued).

```
00255   105*          CALL DCRCIP(DATA(IAA2B),DATA(IAA2P+4), DRL,DIM)
00256   106*          GO TO 55
00257   107*       52 CONTINUE
00260   108*          CALL CASCDE(I A2A)
00261   109*          IA A2A = LOC(I A2A) + 8
00262   110*          CALL DCRCIP(DATA(IA A2A), DATA(IA A2A+4), DRL, DIM)
00263   111*       55 CONTINUE
00264   112*          RMAG = DSQRT(DRL**2+DIM**2)
00265   113*          RDB = 20.*ALOG10(RMAG)
00266   114*          RANG = DCANG1( DRL, DIM  ) * 180./3.14159265
00267   115*          RDF = DDF
00270   116*          RREAL = DRL
00271   117*          RIMAG = DIM
00272   118*          IF ( IF .EQ. 1000 ) CALL PAGE
00274   119*          IF ( L .EQ. 1 ) PRINT 50
00277   120*       50 FORMAT('    F',5X,
00277   121*         /      '    DB',5X, '  MAG',5X, '  ANG DEG ',' REAL',5X,' IMAG' )
00300   122*          PRINT 60, RDF, RDB, RMAG, RANG, RREAL, RIMAG
00310   123*       60 FORMAT(8E10.4)
00311   124*
00311   125*          IF (L.EQ.LTOP) PUNCH 60, RDF, RDB, RMAG, RANG, RREAL, RIMAG
00322   126*
00322   127*          IF ( IF .EQ. 1000 ) GO TO 38
00324   128*          GO TO 40
00325   129*       38 CONTINUE
00326   130*          IF ( L .EQ. LTOP   ) GO TO 39
00330   131*          CALL HEAD 24('  Y A5B                ')
00331   132*          CALL PRT MTR(1YA5B, 5)
00332   133*          CALL HEAD 24('  Y A2B                ')
00333   134*          CALL PRT MTR(1YA2B, 2)
00334   135*          CALL HEAD 24('  A A2B                ')
00335   136*          CALL PRT MTR(1AA2B, 2)
00336   137*          GO TO 40
00337   138*       39 CONTINUE
00340   139*          CALL HEAD 24('   A A2A               ')
00341   140*          CALL PRT MIR(1A A2A, 2)
00342   141*       40 CONTINUE
00343   142*      300 CONTINUE
00345   143*      100 CONTINUE
00347   144*      200 CONTINUE
00351   145*
00351   146*          CALL PAGE
00352   147*          CALL PR PTBL
00353   148*          CALL PR CTLG
00354   149*          CALL TIME
00355   150*          STOP
00356   151*          END

        END OF COMPILATION:        NO  DIAGNOSTICS.
```

Figure F.7. (Continued).

```
@FOR,SW     PRTMTR,PRTMTR,PRTMTR
FOR 0010-10/20/72-15:24:07 (0,0)
-19,19
  100 FORMAT(  2I6, 2D18.10 )

    SUBROUTINE PRTMTR     ENTRY POINT 000077

    STORAGE USED: CODE(1) 000105; DATA(0) 000026; BLANK COMMON(2) 000310

    EXTERNAL REFERENCES (BLOCK, NAME)

     0003   NPRT$
     0004   NI02$
     0005   NI01$
     0006   NERR3$

    STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0000   000005 100F      0000   000010 110F      0001   000020 113G      0001   000023 116G      0002 D 000000 DATA
     0000 I 000004 I         0000   000011 INJP$     0000 I 000003 J         0000 I 000001 K         0000 I 000002 L
     0000 I 000000 MTRMN


 00101      1*           SUBROUTINE PRT MTR ( N MTR, MTR SIZ )
 00103      2*           DOUBLE PRECISION DATA                                             PRTMTR
 00104      3*           COMMON /          / DATA( 100)
 00104      4*     C * * * * * * * PROGRAMMED BY L. E. MCCLEARY  NUC CODE 601 * * * * * * *
 00105      5*
 00105      6*           MTR MN = MTR SIZ**2
 00106      7*           K = N MTR
 00107      8*           L = N MTR + MTR MN
 00110      9*           PRINT 110
 00112     10*           DO 20 J = 1, MTR SIZ
 00115     11*           DO 10 I = 1, MTR SIZ
 00120     12*           PRINT 100, I, J, DATA(K), DATA(L)
 00126     13*           K=K+1
 00127     14*           L=L+1
 00130     15*        10 CONTINUE
 00132     16*           PRINT 110
 00134     17*        20 CONTINUE
 00136     18*           RETURN
 00137     19*       100 FORMAT(  2I6, 2D18.10 )                                          NEW
 00140     20*       110 FORMAT(1H )                                                      -01
 00141     21*           END

       END OF COMPILATION:         NO  DIAGNOSTICS.
```

Figure F.7. (Continued).

SEADUCER RUN 80117 FOR TP-228 APPENDIX F DATE 102072 PAGE 7

@TOP TIME: 15:24:09 DATE: 20 OCT 72 CPU TIME (MILSEC): 3436

@PREP TPF$
FURPUR 023A-10/20-15:24

@PRT,T TPF$.

LMB010314522*TPF$ ELEMENT TABLE

D	NAME	VERSION	TYPE	DATE	TIME	SEQ #	SIZE-PRE	TEXT	(CYCLE	WORD)	PSRMODF	LOCATION
*	CONTRL		FOR SYMB	28 MAR 72	23:16:43	1		26	5	0	1	1792
*	CONTRL		RELOCATABLE	28 MAR 72	23:16:45	2	3	38				1818
	LDPORT		FOR SYMB	28 MAR 72	23:16:45	3		20	5	0	1	1859
	LDPORT		RELOCATABLE	28 MAR 72	23:16:47	4	2	15				1879
	BLDMTR		FOR SYMB	28 MAR 72	23:16:48	5		19	5	0	1	1896
	BLDMTR		RELOCATABLE	28 MAR 72	23:16:49	6	2	11				1915
	BLDKKL		FOR SYMB	28 MAR 72	23:16:50	7		26	5	0	1	1928
	BLDKKL		RELOCATABLE	28 MAR 72	23:16:52	8	3	15				1954
	RDCPRT		FOR SYMB	28 MAR 72	23:16:53	9		39	5	0	1	1973
	RDCPRT		RELOCATABLE	28 MAR 72	23:16:55	10	2	30				2012
	LDFREQ		FOR SYMB	28 MAR 72	23:16:56	11		4	5	0	1	2044
	LDFREQ		RELOCATABLE	28 MAR 72	23:16:57	12	2	3				2048
	UPPTBL		FOR SYMB	28 MAR 72	23:16:58	13		11	5	0	1	2053
	UPPTBL		RELOCATABLE	28 MAR 72	23:17:00	14	2	7				2064
	FNDLCJ		FOR SYMB	28 MAR 72	23:17:00	15		17	5	0	1	2073
	FNDLCJ		RELOCATABLE	28 MAR 72	23:17:02	16	2	11				2090
	ALOCAT		FOR SYMB	28 MAR 72	23:17:03	17		8	5	0	1	2103
	ALOCAT		RELOCATABLE	28 MAR 72	23:17:04	18	2	4				2111
	CHKSTR		FOR SYMB	28 MAR 72	23:17:04	19		3	5	0	1	2117
	CHKSTR		RELOCATABLE	28 MAR 72	23:17:06	20	2	3				2120
	FNDNET		FOR SYMB	28 MAR 72	23:17:06	21		9	5	0	1	2125
	FNDNET		RELOCATABLE	28 MAR 72	23:17:07	22	1	6				2134
	LOCMTR		FOR SYMB	28 MAR 72	23:17:08	23		4	5	0	1	2141
	LOCMTR		RELOCATABLE	28 MAR 72	23:17:09	24	1	3				2145
	LOCNAM		FOR SYMB	28 MAR 72	23:17:10	25		3	5	0	1	2149
	LOCNAM		RELOCATABLE	28 MAR 72	23:17:11	26	1	3				2152
	FNDMTR		FOR SYMB	28 MAR 72	23:17:12	27		4	5	0	1	2156
	FNDMTR		RELOCATABLE	28 MAR 72	23:17:13	28	1	3				2160
	FNDNAM		FOR SYMB	28 MAR 72	23:17:13	29		3	5	0	1	2164
	FNDNAM		RELOCATABLE	28 MAR 72	23:17:15	30	1	3				2167
	CASCDE		FOR SYMB	28 MAR 72	23:17:15	31		16	5	0	1	2171
	CASCDE		RELOCATABLE	28 MAR 72	23:17:17	32	2	9				2187
	TYPCAL		FOR SYMB	28 MAR 72	23:17:18	33		15	5	0	1	2198
	TYPCAL		RELOCATABLE	28 MAR 72	23:17:19	34	2	12				2213
	LDDT1		FOR SYMB	28 MAR 72	23:17:20	35		23	5	0	1	2227
	LDDT1		RELOCATABLE	28 MAR 72	23:17:22	36	2	17				2250
	TYPE1		FOR SYMB	28 MAR 72	23:17:23	37		13	5	0	1	2269
	TYPE1		RELOCATABLE	28 MAR 72	23:17:24	38	2	9				2282
	LDDT2		FOR SYMB	28 MAR 72	23:17:25	39		25	5	0	1	2293
	LDDT2		RELOCATABLE	28 MAR 72	23:17:27	40	2	19				2318
	TYPE2		FOR SYMB	28 MAR 72	23:17:28	41		17	5	0	1	2339
	TYPE2		RELOCATABLE	28 MAR 72	23:17:30	42	2	13				2356
	LDDT4		FOR SYMB	28 MAR 72	23:17:30	43		19	5	0	1	2371

Figure F.7. (Continued).

LDDT4	RELOCATABLE	28	MAR	72	23:17:32	44	2	13				2390
LDDT5	FOR SYMB	28	MAR	72	23:17:33	45		17	5	0	1	2405
LDDT5	RELOCATABLE	28	MAR	72	23:17:34	46	2	11				2422
LDDT7	FOR SYMB	28	MAR	72	23:17:36	47		51	5	0	1	2435
LDDT7	RELOCATABLE	28	MAR	72	23:17:38	48	2	30				2486
TYPE7	FOR SYMB	28	MAR	72	23:17:39	49		28	5	0	1	2518
TYPE7	RELOCATABLE	28	MAR	72	23:17:42	50	1	23				2546
LDDT8	FOR SYMB	28	MAR	72	23:17:42	51		22	5	0	1	2570
LDDT8	RELOCATABLE	28	MAR	72	23:17:44	52	3	20				2592
LDDT9	FOR SYMB	28	MAR	72	23:17:46	53		22	5	0	1	2615
LDDT9	RELOCATABLE	28	MAR	72	23:17:48	54	3	20				2637
LDDT11	FOR SYMB	28	MAR	72	23:17:49	55		26	5	0	1	2660
LDDT11	RELOCATABLE	28	MAR	72	23:17:51	56	3	19				2686
TYPE11	FOR SYMB	28	MAR	72	23:17:52	57		31	5	0	1	2708
TYPE11	RELOCATABLE	28	MAR	72	23:17:55	58	2	29				2739
T11SBR	FOR SYMB	28	MAR	72	23:17:55	59		11	5	0	1	2770
T11SBR	RELOCATABLE	28	MAR	72	23:17:57	60	2	11				2781
LDDT14	FOR SYMB	28	MAR	72	23:17:58	61		25	5	0	1	2794
LDDT14	RELOCATABLE	28	MAR	72	23:18:00	62	3	19				2819
TYPE14	FOR SYMB	28	MAR	72	23:18:00	63		3	5	0	1	2841
TYPE14	RELOCATABLE	28	MAR	72	23:18:01	64	1	2				2844
LDDT15	FOR SYMB	28	MAR	72	23:18:03	65		26	5	0	1	2847
LDDT15	RELOCATABLE	28	MAR	72	23:18:04	66	3	21				2873
TYPE15	FOR SYMB	28	MAR	72	23:18:05	67		3	5	0	1	2897
TYPE15	RELOCATABLE	28	MAR	72	23:18:06	68	1	2				2900
T1415S	FOR SYMB	28	MAR	72	23:18:07	69		9	5	0	1	2903
T1415S	RELOCATABLE	28	MAR	72	23:18:08	70	2	10				2912
TP1415	FOR SYMB	28	MAR	72	23:18:09	71		19	5	0	1	2924
TP1415	RELOCATABLE	28	MAR	72	23:18:11	72	2	20				2943
LDDT20	FOR SYMB	28	MAR	72	23:18:12	73		19	5	0	1	2965
LDDT20	RELOCATABLE	28	MAR	72	23:18:13	74	2	14				2984
TYPE20	FOR SYMB	28	MAR	72	23:18:14	75		13	5	0	1	3000
TYPE20	RELOCATABLE	28	MAR	72	23:18:15	76	2	10				3013
LDDT21	FOR SYMB	28	MAR	72	23:18:16	77		17	5	0	1	3025
LDDT21	RELOCATABLE	28	MAR	72	23:18:18	78	2	12				3042
TYPE21	FOR SYMB	28	MAR	72	23:18:19	79		5	5	0	1	3056
TYPE21	RELOCATABLE	28	MAR	72	23:18:19	80	1	3				3061
LDDT22	FOR SYMB	28	MAR	72	23:18:21	81		17	5	0	1	3065
LDDT22	RELOCATABLE	28	MAR	72	23:18:22	82	2	12				3082
TYPE22	FOR SYMB	28	MAR	72	23:18:22	83		5	5	0	1	3096
TYPE22	RELOCATABLE	28	MAR	72	23:18:24	84	1	4				3101
LDDT24	FOR SYMB	28	MAR	72	23:18:25	85		17	5	0	1	3106
LDDT24	RELOCATABLE	28	MAR	72	23:18:26	86	2	12				3123
TYPE24	FOR SYMB	28	MAR	72	23:18:27	87		5	5	0	1	3137
TYPE24	RELOCATABLE	28	MAR	72	23:18:26	88	1	4				3142
LDDT25	FOR SYMB	28	MAR	72	23:18:29	89		17	5	0	1	3147
LDDT25	RELOCATABLE	28	MAR	72	23:18:30	90	2	12				3164
TYPE25	FOR SYMB	28	MAR	72	23:18:31	91		5	5	0	1	3178
TYPE25	RELOCATABLE	28	MAR	72	23:18:32	92	1	4				3183
LDDT26	FOR SYMB	28	MAR	72	23:18:33	93		19	5	0	1	3188
LDDT26	RELOCATABLE	28	MAR	72	23:18:34	94	2	14				3207
TYPE26	FOR SYMB	28	MAR	72	23:18:35	95		14	5	0	1	3223
TYPE26	RELOCATABLE	28	MAR	72	23:18:37	96	2	13				3237
AIDOD	FOR SYMB	28	MAR	72	23:18:37	97		12	5	0	1	3252
AIDOD	RELOCATABLE	28	MAR	72	23:18:39	98	1	8				3264
LA2RY2	FOR SYMB	28	MAR	72	23:18:39	99		4	5	0	1	3273
LA2RY2	RELOCATABLE	28	MAR	72	23:18:40	100	1	2				3277

Figure F.7. (Continued).

LZ2BY2	FOR SYMB	28 MAR 72	23:18:40	101		4	5	0	1	3280
LZ2BY2	RELOCATABLE	28 MAR 72	23:18:42	102	1	2				3284
LZ3BY3	FOR SYMB	28 MAR 72	23:18:42	103		4	5	0	1	3287
LZ3BY3	RELOCATABLE	28 MAR 72	23:18:43	104	1	2				3291
LY2BY2	FOR SYMB	28 MAR 72	23:18:44	105		4	5	0	1	3294
LY2BY2	RELOCATABLE	28 MAR 72	23:18:45	106	1	2				3298
LY3BY3	FOR SYMB	28 MAR 72	23:18:46	107		4	5	0	1	3301
LY3BY3	RELOCATABLE	28 MAR 72	23:18:47	108	1	2				3305
LDDRIM	FOR SYMB	28 MAR 72	23:18:48	109		5	5	0	1	3308
LDDRIM	RELOCATABLE	28 MAR 72	23:18:49	110	1	4				3313
LDSB11	FOR SYMB	28 MAR 72	23:18:49	111		7	5	0	1	3318
LDSB11	RELOCATABLE	28 MAR 72	23:18:51	112	1	3				3325
LS1415	FOR SYMB	28 MAR 72	23:18:51	113		6	5	0	1	3329
LS1415	RELOCATABLE	28 MAR 72	23:18:52	114	1	3				3335
FNDTMS	FOR SYMB	28 MAR 72	23:18:53	115		9	5	0	1	3339
FNDTMS	RELOCATABLE	28 MAR 72	23:18:54	116	2	5				3348
FNDTL	FOR SYMB	28 MAR 72	23:18:55	117		13	5	0	1	3355
FNDTL	RELOCATABLE	28 MAR 72	23:18:56	118	2	9				3368
MTRMOV	FOR SYMB	28 MAR 72	23:18:57	119		4	5	0	1	3379
MTRMOV	RELOCATABLE	28 MAR 72	23:18:58	120	1	3				3383
MTRMUL	FOR SYMB	28 MAR 72	23:18:59	121		12	5	0	1	3387
MTRMUL	RELOCATABLE	28 MAR 72	23:19:00	122	1	11				3399
DLETRC	FOR SYMB	28 MAR 72	23:19:01	123		11	5	0	1	3411
DLETRC	RELOCATABLE	28 MAR 72	23:19:03	124	1	7				3422
LDIMTR	FOR SYMB	28 MAR 72	23:19:03	125		4	5	0	1	3430
LDIMTR	RELOCATABLE	28 MAR 72	23:19:04	126	1	4				3434
DECOMB	FOR SYMB	28 MAR 72	23:19:06	127		45	5	0	1	3439
DECOMB	RELOCATABLE	28 MAR 72	23:19:10	128	2	55				3484
ATOZ	FOR SYMB	28 MAR 72	23:19:10	129		10	5	0	1	3541
ATOZ	RELOCATABLE	28 MAR 72	23:19:12	130	2	9				3551
ZTOA	FOR SYMB	28 MAR 72	23:19:13	131		10	5	0	1	3562
ZTOA	RELOCATABLE	28 MAR 72	23:19:15	132	2	9				3572
ATOY	FOR SYMB	28 MAR 72	23:19:16	133		9	5	0	1	3583
ATOY	RELOCATABLE	28 MAR 72	23:19:17	134	2	11				3592
YTOA	FOR SYMB	28 MAR 72	23:19:18	135		9	5	0	1	3605
YTOA	RELOCATABLE	28 MAR 72	23:19:19	136	2	11				3614
DACMUL	FOR SYMB	28 MAR 72	23:19:20	137		3	5	0	1	3627
DACMUL	RELOCATABLE	28 MAR 72	23:19:21	138	1	2				3630
DCMMUL	FOR SYMB	28 MAR 72	23:19:22	139		3	5	0	1	3633
DCMMUL	RELOCATABLE	28 MAR 72	23:19:23	140	1	2				3636
DCMDIV	FOR SYMB	28 MAR 72	23:19:24	141		3	5	0	1	3639
DCMDIV	RELOCATABLE	28 MAR 72	23:19:25	142	1	3				3642
DCRCIP	FOR SYMB	28 MAR 72	23:19:25	143		3	5	0	1	3646
DCRCIP	RELOCATABLE	28 MAR 72	23:19:27	144	1	2				3649
DCSQRT	FOR SYMB	28 MAR 72	23:19:28	145		10	5	0	1	3652
DCSQRT	RELOCATABLE	28 MAR 72	23:19:29	146	1	9				3662
DCANG1	FOR SYMB	28 MAR 72	23:19:30	147		8	5	0	1	3672
DCANG1	RELOCATABLE	28 MAR 72	23:19:31	148	1	6				3680
DCACSH	FOR SYMB	28 MAR 72	23:19:32	149		5	5	0	1	3687
DCALSH	RELOCATABLE	28 MAR 72	23:19:33	150	1	4				3692
DSHCH	FOR SYMB	28 MAR 72	23:19:34	151		4	5	0	1	3697
DSHCH	RELOCATABLE	28 MAR 72	23:19:35	152	1	3				3701
DCSHCS	FOR SYMB	28 MAR 72	23:19:36	153		5	5	0	1	3705
DCSNCS	RELOCATABLE	28 MAR 72	23:19:37	154	1	3				3710
DCSHCH	FOR SYMB	28 MAR 72	23:19:37	155		5	5	0	1	3714
DCSHCH	RELOCATABLE	28 MAR 72	23:19:39	156	1	3				3719
* PRTMTR	FOR SYMB	28 MAR 72	23:19:40	157		5	5	0	1	3723

Figure F.7. (Continued).

*	PRTMTR	RELOCATABLE	28 MAR 72	23:19:41	158	1	5				3728
	PRTMBN	FOR SYMB	28 MAR 72	23:19:42	159		5	5	0	1	3734
	PRTMBN	RELOCATABLE	28 MAR 72	23:19:43	160	1	5				3739
	PRMARI	FOR SYMB	28 MAR 72	23:19:43	161		8	5	0	1	3745
	PRMARI	RELOCATABLE	28 MAR 72	23:19:45	162	2	6				3753
	HEAD24	FOR SYMB	28 MAR 72	23:19:45	163		6	5	0	1	3761
	HEAD24	RELOCATABLE	28 MAR 72	23:19:47	164	1	6				3767
	PAGE	FOR SYMB	28 MAR 72	23:19:48	165		1	5	0	1	3774
	PAGE	RELOCATABLE	28 MAR 72	23:19:49	166	1	2				3775
	STRLIN	FOR SYMB	28 MAR 72	23:19:49	167		2	5	0	1	3778
	STRLIN	RELOCATABLE	28 MAR 72	23:19:51	168	1	2				3780
	SKPLIN	FOR SYMB	28 MAR 72	23:19:51	169		2	5	0	1	3783
	SKPLIN	RELOCATABLE	28 MAR 72	23:19:52	170	1	2				3785
	PRPTBL	FOR SYMB	28 MAR 72	23:19:53	171		7	5	0	1	3788
	PRPTBL	RELOCATABLE	28 MAR 72	23:19:54	172	1	5				3795
	PRCTLG	FOR SYMB	28 MAR 72	23:19:55	173		6	5	0	1	3801
	PRCTLG	RELOCATABLE	28 MAR 72	23:19:55	174	2	5				3807
	UNPACK	FOR SYMB	28 MAR 72	23:19:57	175		26	5	0	1	3814
	UNPACK	RELOCATABLE	28 MAR 72	23:19:59	176	1	22				3840
	BLKDTA	FOR SYMB	28 MAR 72	23:20:00	177		15	5	0	1	3863
	BLKDTA	RELOCATABLE	28 MAR 72	23:20:00	178	4	3				3878
	TIME	FOR SYMB	28 MAR 72	23:20:01	179		5	5	0	1	3885
	TIME	RELOCATABLE	28 MAR 72	23:20:02	180	1	3				3890
	Z1TOZ2	FOR SYMB	28 MAR 72	23:20:03	181		8	5	0	1	3894
	Z1TOZ2	RELOCATABLE	28 MAR 72	23:20:04	182	1	6				3902
	DCPCT2	FOR SYMB	28 MAR 72	23:20:05	183		9	5	0	1	3909
	DCPCT2	RELOCATABLE	28 MAR 72	23:20:06	184	1	7				3918
	FNDKRC	FOR SYMB	28 MAR 72	23:20:07	185		26	5	0	1	3926
	FNDKRC	RELOCATABLE	28 MAR 72	23:20:09	186	2	20				3952
	SRCHBC	FOR SYMB	28 MAR 72	23:20:12	187		101	5	0	1	3974
	SRCHBC	RELOCATABLE	28 MAR 72	23:20:16	188	4	76				4075
	MINCHK	FOR SYMB	28 MAR 72	23:20:16	189		3	5	0	1	4155
	MINCHK	RELOCATABLE	28 MAR 72	23:20:18	190	1	2				4158
	MAXCHK	FOR SYMB	28 MAR 72	23:20:18	191		3	5	0	1	4161
	MAXCHK	RELOCATABLE	28 MAR 72	23:20:19	192	1	2				4164
	CMPZS	FOR SYMB	28 MAR 72	23:20:19	193		5	5	0	1	4167
	CMPZS	RELOCATABLE	28 MAR 72	23:20:21	194	2	3				4172
	PREPZV	FOR SYMB	28 MAR 72	23:20:22	195		16	5	0	1	4177
	PREPZV	RELOCATABLE	28 MAR 72	23:20:23	196	2	18				4193
	FNDFZV	FOR SYMB	28 MAR 72	23:20:24	197		7	5	0	1	4213
	FNDFZV	RELOCATABLE	28 MAR 72	23:20:25	198	2	5				4220
	LDZRVR	FOR SYMB	28 MAR 72	23:20:25	199		5	5	0	1	4227
	LDZRVR	RELOCATABLE	28 MAR 72	23:20:27	200	2	3				4232
	SRMIDB	FOR SYMB	28 MAR 72	23:20:29	201		57	5	0	1	4237
	SRMIDB	RELOCATABLE	28 MAR 72	23:20:32	202	4	50				4294
	LDAM2S	FOR SYMB	28 MAR 72	23:20:33	203		19	5	0	1	4348
	LDAM2S	RELOCATABLE	28 MAR 72	23:20:34	204	3	15				4367
	CMPGAM	FOR SYMB	28 MAR 72	23:20:36	205		16	5	0	1	4385
	CMPGAM	RELOCATABLE	28 MAR 72	23:20:37	206	2	14				4401
	FSRCH	FOR SYMB	28 MAR 72	23:20:41	207		142	5	0	1	4417
	FSRCH	RELOCATABLE	28 MAR 72	23:20:48	208	5	123				4559
	RLIMMG	FOR SYMB	28 MAR 72	23:20:48	209		10	5	0	1	4687
	RLIMMG	RELOCATABLE	28 MAR 72	23:20:49	210	2	6				4697
	FMFN	FOR SYMB	28 MAR 72	23:20:50	211		6	5	0	1	4705
	FMFN	RELOCATABLE	28 MAR 72	23:20:51	212	2	5				4711
	POLEO	FOR SYMB	28 MAR 72	23:20:52	213		14	5	0	1	4718
	POLEO	RELOCATABLE	28 MAR 72	23:20:54	214	1	13				4732

Figure F.7. (Continued).

PRBFIT	FOR SYMB	28 MAR 72	23:20:54	215		9	5	0	1	4746
PRBFIT	RELOCATABLE	28 MAR 72	23:20:55	216	1	7				4755
FNDPRM	FOR SYMB	28 MAR 72	23:20:57	217		40	5	0	1	4763
FNDPRM	RELOCATABLE	28 MAR 72	23:21:00	218	4	29				4803
FNDFDP	FOR SYMB	28 MAR 72	23:21:00	219		8	5	0	1	4836
FNDFDP	RELOCATABLE	28 MAR 72	23:21:01	220	2	3				4844
LDBCOL	FOR SYMB	28 MAR 72	23:21:02	221		6	5	0	1	4849
LDBCOL	RELOCATABLE	28 MAR 72	23:21:03	222	2	4				4855
PRTPRM	FOR SYMB	28 MAR 72	23:21:04	223		14	5	0	1	4861
PRTPRM	RELOCATABLE	28 MAR 72	23:21:05	224	2	9				4875
CONTRL	FOR SYMB	20 OCT 72	15:24:02	225		34	5	0	1	4886
CONTRL	RELOCATABLE	20 OCT 72	15:24:04	226	4	38				4920
PRTMTR	FOR SYMB	20 OCT 72	15:24:07	227		5	5	0	1	4962
PRTMTR	RELOCATABLE	20 OCT 72	15:24:09	228	1	5				4967
NEXT AVAILABLE LOCATION-										4973

ASSEMBLER PROCEDURE TABLE EMPTY

COBOL PROCEDURE TABLE EMPTY

FORTRAN PROCEDURE TABLE EMPTY

ENTRY POINT TABLE

D NAME	LINK	D NAME	LINK	D NAME	LINK	D NAME	LINK	D NAME	LINK
AIDOD	98	ALOCAT	18	ATOY	134	ATOZ	130	BLDKKL	8
BLDMTR	6	CASCDE	32	CHKSTR	20	CMPGAM	206	CMPZS	194
DACMUL	138	DCACSH	150	DCANG1	148	DCMDIV	142	DCMMUL	140
DCPCT2	164	DCRCIP	144	DCSHCH	156	DCSNCS	154	DCSQRT	146
DECOMB	128	DLETRC	124	DSHCH	152	FMFN	212	FNDFDP	220
FNDFZV	198	FNDKRC	186	FNDLCJ	16	FNDMTR	28	FNDNAM	30
FNDNET	22	FNDPRM	218	FNDTL	118	FNDTMS	116	FORMAIN$	226
FSRCH	208	HEAD24	164	LA2BY2	100	LDAM2S	204	LDBCOL	222
LDDRIM	110	LDDT1	36	LDDT11	56	LDDT14	62	LDDT15	66
LDDT2	40	LDDT20	74	LDDT21	78	LDDT22	82	LDDT24	86
LDDT25	90	LDDT26	94	LDDT4	44	LDDT5	46	LDDT7	48
LDDT8	52	LDDT9	54	LDFREQ	12	LDIMTR	126	LDPORT	4
LDSB11	112	LDZRVR	200	LOCMTR	24	LOCNAM	26	LS1415	114
LY2BY2	106	LY3BY3	108	LZ2BY2	102	LZ3BY3	104	MAXCHK	192
MINCHK	190	MTRMOV	120	MTRMUL	122	PAGE	166	POLEO	214
PRBFIT	216	PRCTLG	174	PREPZV	196	PRMARI	162	PRPTBL	172
PRIMBN	160	PRTMTR	228	PRTPRM	224	RDCPRT	10	RLIMMG	210
SKPLIN	170	SRCHBC	188	SRMIOB	202	STRLIN	168	TIME	180
TP1415	72	TYPCAL	34	TYPE1	38	TYPE11	58	TYPE14	64
TYPE15	68	TYPE2	42	TYPE20	76	TYPE21	80	TYPE22	84
TYPE24	88	TYPE25	92	TYPE26	96	TYPE7	50	T11SBR	60
T1415S	70	UNPACK	176	UPPTBL	14	YTOA	136	ZTOA	132
Z1IOZ2	102								

Figure F.7. (Continued).

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SEADUCER RUN 80117 FOR TP-228 APPENDIX F                                        DATE 102072          PAGE   12

@MAP,XIB      SYMRUN,ABSRUN
MAP 0022-10/20-15:24 -(,0)

    1.        IN CONTRL

    2.        IN BLKDTA


ADDRESS LIMITS     001000 027762      040000 056002
STARTING ADDRESS   027043

WORDS DECIMAL       11763 IBANK         7171 DBANK


             SEGMENT MAIN                001000 027762      040000 056002

NBDCV$/FOR57                 1    001000 001133      2    040000 040037
NFTV$/FOR                    1    001134 001156
NCNVT$/FOR57                 1    001157 001411      2    040040 040127
NIOER$/FOR57                 1    001412 001530      2    040130 040232
NOUI$/FOR57-UNIV             1    001531 002500      2    040233 040263
NFMT$/FOR57                  1    002501 003405      2    040264 040302
NTAB$/FOR                                            2    040303 040341
ERU$/57
DEXP$/FOR54                  1    003406 003554      2    040342 040375
DLOG$/FOR54                  1    003555 003675      2    040376 040502
DSINCOS$/FOR57               1    003676 004037      2    040503 040561
DLOG10$/FOR54                1    004040 004050      2    040562 040565
DATAN$/FOR54                 1    004051 004177      2    040566 040650
NERR$/FOR57-NUC              1    004200 004541      2    040651 041025
NSTOP$/NUC                   1    004542 004565      2    041026 041034
ALOG$/FOR51                  1    004566 004703      2    041035 041075
DSQRT$/FOR57                 1    004704 004753      2    041076 041114
NEXP1$/FOR54                 1    004754 005007      0    041115 041115
NIER$/FOR52                  1    005010 005072      2    041116 041245
NOSYM$/FOR57                 1    005073 005325      2    041246 041253
NINTR$/NUC                   1    005326 005362      2    041254 041273
DATE-TIME/NUC-PACK           1    005363 005412      0    041274 041331
I1415S                       1    005413 005655      0    041332 041355
                             3    CS1415             2    BLANK$COMMON
                                                     4    CM1415
DCSQRT                       1    005656 006104      0    041356 041412
                                                     2    BLANK$COMMON
DSHCH                        1    006105 006143      0    041413 041427
                                                     2    BLANK$COMMON
LY3BY3                       1    006144 006173      0    041430 041440
                             3    CY3BY3             2    BLANK$COMMON
CS1415 (COMMON BLOCK)                                     041441 041444
```

Figure F.7. (Continued).

```
TP1415                 1  006174 006740     0  041445 041531
                       3  CS1415            2  BLANK$COMMON
                       5  CM1415            4  BASIC8
                                            6  CZ3BY3
CM1415 (COMMON BLOCK)                          041532 041563
LS1415                 1  006741 007007     0  041564 041576
                       3  CM1415            2  BLANK$COMMON
                                            4  CEGSFP
DCSHCH                 1  007010 007067     0  041577 041615
                                            2  BLANK$COMMON
DCACSH                 1  007070 007161     0  041616 041640
                                            2  BLANK$COMMON
T11SBR                 1  007162 007456     0  041641 041675
                       3  COMN11            2  BLANK$COMMON
LZ3BY3                 1  007457 007506     0  041676 041706
                       3  CZ3BY3            2  BLANK$COMMON
CEGSFP (COMMON BLOCK)                          041707 041714
LDSS11                 1  007507 007555     0  041715 041727
                       3  COMN11            2  BLANK$COMMON
                                            4  CEGSFP
ZTUA                   1  007556 010002     0  041730 041766
                       3  CA2BY2            2  BLANK$COMMON
                                            4  CZ2BY2
DCSHCS                 1  010003 010065     0  041767 042005
                                            2  BLANK$COMMON
LZ2BY2                 1  010066 010115     0  042006 042016
                       3  CZ2BY2            2  BLANK$COMMON
CY3BY3 (COMMON BLOCK)                          042017 042040
TYPE26                 1  010116 010463     0  042041 042102
                       3  BASIC8            2  BLANK$COMMON
                       5  COMN26            4  CY3BY3
TYPE25                 1  010464 010545     0  042103 042122
                       3  BASIC8            2  BLANK$COMMON
TYPE24                 1  010546 010645     0  042123 042142
                       3  BASIC8            2  BLANK$COMMON
TYPE22                 1  010646 010744     0  042143 042162
                       3  BASIC8            2  BLANK$COMMON
TYPE21                 1  010745 011025     0  042163 042202
                       3  BASIC8            2  BLANK$COMMON
TYPE20                 1  011026 011261     0  042203 042270
                       3  BASIC8            2  BLANK$COMMON
                                            4  CA2BY2
CMN15C (COMMON BLOCK)                          042271 042272
TYPE15                 1  011262 011306     0  042273 042277
                       3  CMN15C            2  BLANK$COMMON
TYPE14                 1  011307 011333     0  042300 042304
                                            2  BLANK$COMMON
CZ3BY3 (COMMON BLOCK)                          042305 042326
COMN11 (COMMON BLOCK)                          042327 042367
TYPE11                 1  011334 012350     0  042370 042460
                       3  BASIC8            2  BLANK$COMMON
                       5  CZ3BY3            4  COMN11
TYPE7                  1  012351 013203     0  042461 042553
                       3  BASIC8            2  BLANK$COMMON
TYPE2                  1  013204 013541     0  042554 042674
                       3  BASIC8            2  BLANK$COMMON
                                            4  CA2BY2
```

Figure F.7. (Continued).

TYPE1	1	013542 013756	0	042675 042766
	3	BASIC6	2	BLANK$COMMON
			4	CA2BY2
DCMSOL (COMMON BLOCK)				042767 043404
DECOND (COMMON BLOCK)				043405 043406
VALDET (COMMON BLOCK)				043407 043412
DECOMB	1	013757 015720	0	043413 043637
	3	VALDET	2	BLANK$COMMON
	5	DCMSOL	4	DECOND
DCMDIV	1	015721 015766	0	043640 043652
			2	BLANK$COMMON
FNDLCJ	1	015767 016266	0	043653 043701
	3	PRTTBL	2	BLANK$COMMON
			4	CATALG
FNDNET	1	016267 016437	0	043702 043724
	3	PRTTBL	2	BLANK$COMMON
MTRMUL	1	016440 016710	0	043725 044022
			2	BLANK$COMMON
ATOY	1	016711 017216	0	044023 044052
	3	CA2BY2	2	BLANK$COMMON
			4	CY2BY2
CZ2BY2 (COMMON BLOCK)				044053 044062
ATOZ	1	017217 017443	0	044063 044121
	3	CA2BY2	2	BLANK$COMMON
			4	CZ2BY2
TYPCAL	1	017444 017746	0	044122 044146
	3	CATALG	2	BLANK$COMMON
DACMUL	1	017747 020007	0	044147 044155
			2	BLANK$COMMON
DCMMUL	1	020010 020044	0	044156 044164
			2	BLANK$COMMON
LY2BY2	1	020045 020074	0	044165 044175
	3	CY2BY2	2	BLANK$COMMON
LA2BY2	1	020075 020124	0	044176 044206
	3	CA2BY2	2	BLANK$COMMON
RDCPRT	1	020125 021143	0	044207 044330
	3	CATALG	2	BLANK$COMMON
			4	CNMRDC
BLDKKL	1	021144 021555	0	044331 044415
	3	PRTTBL	2	BLANK$COMMON
	5	CNMRDC	4	CATALG
	7	CMAGIC	6	CPRTIN
			8	CFLGAZ
FNDMTR	1	021556 021633	0	044416 044426
	3	CATALG	2	BLANK$COMMON
LDIMTR	1	021634 021724	0	044427 044452
			2	BLANK$COMMON
CHKSTR	1	021725 021755	0	044453 044470
	3	DTATOT	2	BLANK$COMMON
SKPLIN	1	021756 022010	0	044471 044500
			2	BLANK$COMMON
ALOCAT	1	022011 022072	0	044501 044525
	3	CATALG	2	BLANK$COMMON
			4	DTASUB
UPPTBL	1	022073 022264	0	044526 044550
	3	PRTTBL	2	BLANK$COMMON
			4	CUPTBL

Figure F.7. (Continued).

UNPACK	1	022265 023050	0	044551 044656
	3	CPTWRD	2	BLANK$COMMON
TIME	1	023051 023077	0	044657 044703
			2	BLANK$COMMON
PRCTLG	1	023100 023154	0	044704 044761
	3	CATALG	2	BLANK$COMMON
			4	DTASUB
PRPTBL	1	023155 023233	0	044762 045040
	3	PRTTBL	2	BLANK$COMMON
PRTMTR	1	023234 023340	0	045041 045066
			2	BLANK$COMMON
HEAD24	1	023341 023463	0	045067 045110
	3	CPTWRD	2	BLANK$COMMON
DCANG1	1	023464 023622	0	045111 045133
			2	BLANK$COMMON
CASCDE	1	023623 024055	0	045134 045156
	3	CATALG	2	BLANK$COMMON
			4	CFLGAZ
DCRCIP	1	024056 024110	0	045157 045165
			2	BLANK$COMMON
MTRMOV	1	024111 024157	0	045166 045203
			2	BLANK$COMMON
CY2BY2 (COMMON BLOCK)				045204 045213
CA2BY2 (COMMON BLOCK)				045214 045223
YTOA	1	024160 024463	0	045224 045251
	3	CA2BY2	2	BLANK$COMMON
			4	CY2BY2
LOCMTR	1	024464 024540	0	045252 045263
	3	CATALG	2	BLANK$COMMON
ENDNAM	1	024541 024604	0	045264 045274
	3	CATALG	2	BLANK$COMMON
BLDMTR	1	024605 025063	0	045275 045326
	3	PRTTBL	2	BLANK$COMMON
	5	CPRTIN	4	CATALG
	7	CMAGIC	6	CNMRDC
			8	CBLD
LDDT22	1	025064 025341	0	045327 045410
	3	CATALG	2	BLANK$COMMON
	5	PRTOFF	4	DTASUB
LDDT21	1	025342 025617	0	045411 045472
	3	CATALG	2	BLANK$COMMON
	5	PRTOFF	4	DTASUB
LDFREQ	1	025620 025650	0	045473 045506
	3	BASIC6	2	BLANK$COMMON
			4	PRTOFF
COMN26 (COMMON BLOCK)				045507 045522
LDDT26	1	025651 026172	0	045523 045635
	3	CATALG	2	BLANK$COMMON
	5	PRTOFF	4	DTASUB
			6	COMN26
LDDT4	1	026173 026465	0	045636 045726
	3	CATALG	2	BLANK$COMMON
	5	PRTOFF	4	DTASUB
LDPORT	1	026466 027010	0	045727 046016
	3	PRTTBL	2	BLANK$COMMON
			4	CPTWRD
STRLIN	1	027011 027025	0	046017 046042

Figure F.7. (Continued).

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SEAJUCER RUN 69117 FOR TP-228 APPENDIX F                                              DATE 102072        PAGE    16

                                                          2    BLANK$COMMON
PAGE                                 1    027026 027042   0    046043 046050
                                                          2    BLANK$COMMON
CSRHBC  (COMMON BLOCK)                                         046051 046051
CMNFMN  (COMMON BLOCK)                                         046052 046054
CFMNPR  (COMMON BLOCK)                                         046055 046055
PRGMTR  (COMMON BLOCK)                                         046056 046056
CSRMTR  (COMMON BLOCK)                                         046057 046057
CUPTBL  (COMMON BLOCK)                                         046060 046060
CPRBFT  (COMMON BLOCK)                                         046061 046064
CSTACK  (COMMON BLOCK)                                         046065 046065
CNMRDC  (COMMON BLOCK)                                         046066 046067
CPRTIN  (COMMON BLOCK)                                         046070 046071
CMAGIC  (COMMON BLOCK)                                         046072 046072
CBLD (COMMON BLOCK)                                            046073 046073
CFLGAZ  (COMMON BLOCK)                                         046074 046074
CPTWRD  (COMMON BLOCK)                                         046075 046076
BASIC8  (COMMON BLOCK)                                         046077 046104
PRTOFF  (COMMON BLOCK)                                         046105 046105
DTATOT  (COMMON BLOCK)                                         046106 046106
DTASUB  (COMMON BLOCK)                                         046107 046107
CATALG  (COMMON BLOCK)                                         046110 047404
PRTTBL  (COMMON BLOCK)                                         047405 051521
BLANK$COMMON (COMMON BLOCK)                                    051522 055441
 CONTRL                              1    027043 027762   0    055442 056002
                                     3    CATALG          2    BLANK$COMMON
                                     5    DTATOT          4    PRTOFF
 BLKDTA                              3    PRTTBL          2    BLANK$COMMON
                                     5    DTASUB          4    CATALG
                                     7    PRTOFF          6    DTATOT
                                     9    CPTWRD          8    BASIC8
                                    11    CBLD           10    CFLGAZ
                                    13    CPRTIN         12    CMAGIC
                                    15    CSTACK         14    CNMRDC
                                    17    CUPTBL         16    CPRBFT
                                    19    PRGMTR         18    CSRMTR
                                    21    CMNFMN         20    CFMNPR
                                                         22    CSRHBC

 SYS$*RLIB$. LEVEL 57
 END OF COLLECTION - TIME 3.028 SECONDS
```

Figure F.7. (Continued).

SEAJUCER RUN 80117 FOR TP-22P APPENDIX F DATE 102072 PAGE 17

0X01 ABSPUN

Figure F.7. (Continued).

```
****************************************************************************************
SEADUCER RUN 80117F  MAR 21,1972 $
HI PASS - LO PASS CASCADE $
W/ 1/2 DB RIPPLE FACTOR, (FLP=2850, FHP=2150) $
CHARGE TO 16000401 AMPLIFIERS

* * * * * AB  5 NETWORK TABLE

P  1A5B,  1B2A,$
P  2A5B,   2B2C,  2B2D,-+3B3E,$
P  3A5B, -+2B2A,  1B2B,  1B2C,$
P  4A5B, -+2B2B,  1B2D,  1B3E,$
P  5A5B,  2B3E,$

TYPE 4          UNIT MATRIX
A2A1$            1.00

TYPE 4          UNIT MATRIX
A2A2$            1.00

TYPE 4          UNIT MATRIX
A2A3$            1.00

TYPE 4          UNIT MATRIX
A2A4$            1.00

TYPE 4          UNIT MATRIX
A2A5$            1.00

TYPE 4          UNIT MATRIX
A2A6$            1.00

TYPE 4          UNIT MATRIX
A2A7$            1.00

TYPE 4          UNIT MATRIX
A2A8$            1.00

TYPE 26            R1            C1            R2            C2
B3E$          .100000+07    .700000-12    .100000-09    .100000-09
                   RD            CD            R3            L3
              .100000+07    .700000-12    .750000+02    .000000
                   A0          OMEGA1        OMEGA2        OMEGA3
              .700000+05    .628318+02    .188495+08    .628318+10
```

Figure F.7. (Continued).

F	DB	MAG	ANG DEG	REAL	IMAG
.1000+04	-.3434+02	.1918-01	-.1168+02	.1877-01	-.3949-02

Y A5B

1	1	.0000000000	.3330088209-004
2	1	.0000000000	.0000000000
3	1	.0000000000	-.3330088209-004
4	1	.0000000000	.0000000000
5	1	.0000000000	.0000000000
1	2	.0000000000	.0000000000
2	2	-.1345167653-001	-.3330088209-004
3	2	.0000000000	-.3330088209-004
4	2	-.1183431953-003	-.2228982791-041
5	2	.0000000000	.0000000000
1	3	.0000000000	-.3330088209-004
2	3	.0000000000	.3330088209-004
3	3	.4878048780-003	.9990264628-004
4	3	.0000000000	-.3330088209-004
5	3	.0000000000	.0000000000
1	4	.0000000000	.0000000000
2	4	-.9008535753-001	.9332422371+001
3	4	.0000000000	-.3330088209-004
4	4	.1203431953-003	.3330967855-004
5	4	-.1000000000-005	-.4398229723-008
1	5	.0000000000	.0000000000
2	5	.9020370072-001	-.9332422371+001
3	5	.0000000000	.0000000000
4	5	-.1000000000-005	-.4398229723-008
5	5	.1000000004+011	.6327167579-006

Y A2B

1	1	.2151089024-005	.3287820161-004
2	1	-.7192004976-001	-.1472234110+000
1	2	.4009038268-005	-.1552596380-005
2	2	.2088853724+001	.8283490378+001

A A2B

1	1	.5102032354+002	.1073559207+002
2	1	-.2392066642-003	.1699197102-002
1	2	-.2678863319+001	.5483747532+001
2	2	-.1860562304-003	-.7628017916-004

Figure F.7. (Continued).

.1000+04 -.2164+02 .8280-01 -.1078+02 .8134-01 -.1548-01

Y A5B

1	1	.0000000000	.3330088209-004
2	1	.0000000000	.0000000000
3	1	.0000000000	-.3330088209-004
4	1	.0000000000	.0000000000
5	1	.0000000000	.0000000000
1	2	.0000000000	.0000000000
2	2	-.1335820896-001	-.3330088209-004
3	2	.0000000000	-.3330088209-004
4	2	-.2487562189-004	-.9848453238-043
5	2	.0000000000	.0000000000
1	3	.0000000000	-.3330088209-004
2	3	.0000000000	.3330088209-004
3	3	.5747126437-003	.9990264628-004
4	3	.0000000000	-.3330088209-004
5	3	.0000000000	.0000000000
1	4	.0000000000	.0000000000
2	4	-.9017862510-001	.9332422371+001
3	4	.0000000000	-.3330088209-004
4	4	.2687562189-004	.3330967855-004
5	4	-.1000000000-005	-.4396229723-008
1	5	.0000000000	.0000000000
2	5	.9020370072-001	-.9332422371+001
3	5	.0000000000	.0000000000
4	5	-.1000000000-005	-.4396229723-008
5	5	.1000000004+011	.6327167579-006

Y A2B

1	1	.1842900278-005	.3305223052-004
2	1	-.3447546656+000	-.2134847160+000
1	2	.2403013612-005	-.1173004428-005
2	2	.3607950398+001	.3311273067+001

A A2B

1	1	.1186368721+002	.2258293362+001
2	1	-.5037502670-004	.3951101294-003
1	2	-.2096646071+001	.1296320040+001
2	2	-.4677628207-004	-.6690615489-004

Figure F.7. (Continued).

.1000+04 -.1446+02 .1692+00 -.7932+01 .1874+00 -.2611-01

Y A5B

1	1	.0000000000	.3330088209-004
2	1	.0000000000	.0000000000
3	1	.0000000000	-.3330088209-004
4	1	.0000000000	.0000000000
5	1	.0000000000	.0000000000
1	2	.0000000000	.0000000000
2	2	-.1334133333-001	-.3330088209-004
3	2	.0000000000	-.3330088209-004
4	2	-.8000000000-005	-.1016591640-043
5	2	.0000000000	.0000000000
1	3	.0000000000	-.3330088209-004
2	3	.0000000000	.3330088209-004
3	3	.8695652174-003	.9990264628-004
4	3	.0000000000	-.3330088209-004
5	3	.0000000000	.0000000000
1	4	.0000000000	.0000000000
2	4	-.9019570072-001	.9332422371+001
3	4	.0000000000	-.3330088209-004
4	4	.1000000000-004	.3330967855-004
5	4	-.1000000000-005	-.4396229723-008
1	5	.0000000000	.0000000000
2	5	.9020370072-001	-.9332422371+001
3	5	.0000000000	.0000000000
4	5	-.1000000000-005	-.4396229723-008
5	5	.1000000004+011	.6327167579-006

Y A2B

1	1	.1254170663-005	.3320188386-004
2	1	-.3292821296+000	-.7451386540-001
1	2	.1315312201-005	-.3616574562-006
2	2	.1669276680+001	.6301982737+000

A A2B

1	1	.5234490162+001	.7293325594+000
2	1	-.1633495857-004	.1743277845-003
1	2	-.2888970975+001	.6537506139+000
2	2	-.2532901465-004	-.9509936391-004

Figure F.7. (Continued).

```
 .1000+04 -.1152+02  .2656+00 -.3147+01  .2652+00 -.1458-01
 Y A5B

   1     1   .0000000000       .3330088209-004
   2     1   .0000000000       .0000000000
   3     1   .0000000000      -.3330088209-004
   4     1   .0000000000       .0000000000
   5     1   .0000000000       .0000000000

   1     2   .0000000000       .0000000000
   2     2  -.1333500300-001  -.3330088209-004
   3     2   .0000000000      -.3330088209-004
   4     2  -.2169680841-005  -.7492154369-045
   5     2   .0000000000       .0000000000

   1     3   .0000000000      -.3330088209-004
   2     3   .0000000000       .3330088209-004
   3     3   .2487562189-002   .9990264628-004
   4     3   .0000000000      -.3330088209-004
   5     3   .0000000000       .0000000000

   1     4   .0000000000       .0000000000
   2     4  -.9020133105-001   .9332422371+001
   3     4   .0000000000      -.3330088209-004
   4     4   .4169680841-005   .3330967855-004
   5     4  -.1000000000-005  -.4398229723-008

   1     5   .0000000000       .0000000000
   2     5   .9020370072-001  -.9332422371+001
   3     5   .0000000000       .0000000000
   4     5  -.1000000000-005  -.4398229723-008
   5     5   .1000000004+011   .6327167579-006

 Y A2B

   1     1   .4447405120-006   .3326890101-004
   2     1  -.1229785975+000  -.1324187760-001

   1     2   .4475424768-006  -.4659907055-007
   2     2   .4596257677+000   .7520971734-001

 A A2B

   1     1   .3759696675+001   .2067368845+000
   2     1  -.4762411782-005   .1252075156-003

   1     2  -.8038279563+001   .3655299100+000
   2     2  -.3236749806-004  -.2672005565-003
```

Figure F.7. (Continued).

```
.1000+04  .1122+01  .1136+01  .1761+03 -.1137+01  .3731-01
 Y A5B

  1   1    .3086419753-004    .1516107908-042
  2   1    .0000000000        .0000000000
  3   1   -.3086419753-004   -.1516107908-042
  4   1    .0000000000        .0000000000
  5   1    .0000000000        .0000000000

  1   2    .0000000000        .0000000000
  2   2   -.1336419753-001   -.2636937818-006
  3   2   -.3086419753-004   -.1516107908-042
  4   2    .0000000000       -.2636937818-006
  5   2    .0000000000        .0000000000

  1   3   -.3086419753-004   -.1516107908-042
  2   3    .3086419753-004    .1516107908-042
  3   3    .9259259259-004    .3725928889-003
  4   3   -.3086419753-004   -.1516107908-042
  5   3    .0000000000        .0000000000

  1   4    .0000000000        .0000000000
  2   4   -.9020370072-001    .9332422635+001
  3   4   -.3086419753-004   -.1516107908-042
  4   4    .3286419753-004    .2726902413-006
  5   4   -.1000000000-005   -.4396229723-008

  1   5    .0000000000        .0000000000
  2   5    .9020370072-001   -.9332422371+001
  3   5    .0000000000        .0000000000
  4   5   -.1000000000-005   -.4396229723-008
  5   5    .1000000004+011    .6327167579-006

 Y A2B

  1   1    .3044061692-004    .2482758600-005
  2   1    .7048710544+000    .1212472734+000

  1   2   -.4435435759-006    .2479522964-005
  2   2    .6156417110+000    .1266121713+000

 A A2B

  1   1   -.8783673742+000   -.2681735891-001
  2   1   -.2711004178-004   -.5784693715-006

  1   2    .1377926214+001   -.2370221302+000
  2   2    .4253345364-004   -.5794036743-005
```

Figure F.7. (Continued).

.1000+04 .1550+01 .1195+01 .1717+03 -.1183+01 .1718+00

Y A5B

1	1	.3086419753-004	.1516107908-042
2	1	.0000000000	.0000000000
3	1	-.3086419753-004	-.1516107908-042
4	1	.0000000000	.0000000000
5	1	.0000000000	.0000000000
1	2	.0000000000	.0000000000
2	2	-.1336419753-001	-.1206371574-005
3	2	-.3086419753-004	-.1516107908-042
4	2	.0000000000	-.1206371574-005
5	2	.0000000000	.0000000000
1	3	-.3086419753-004	-.1516107908-042
2	3	.3086419753-004	.1516107908-042
3	3	.9259259259-004	.1306902540-003
4	3	-.3086419753-004	-.1516107908-042
5	3	.0000000000	.0000000000
1	4	.0000000000	.0000000000
2	4	-.9020370072-001	.9332423577+001
3	4	-.3086419753-004	-.1516107908-042
4	4	.3286419753-004	.1215168034-005
5	4	-.1000000000-005	-.4398229723-008
1	5	.0000000000	.0000000000
2	5	.9020370072-001	-.9332422371+001
3	5	.0000000000	.0000000000
4	5	-.1000000000-005	-.4398229723-008
5	5	.1000000004+011	.6327167579-006

Y A2B

1	1	.2803259762-004	.5861981527-005
2	1	.1684876563+001	.7576722965+000
1	2	-.3050324466-005	.5766127229-005
2	2	.1303787228+001	.8300047804+000

A A2B

1	1	-.8278961635+000	-.1202255513+000
2	1	-.2555364453-004	-.2457219290-005
1	2	.4936384352+000	-.2220429097+000
2	2	.1513957906-004	-.3330740153-005

Figure F.7. (Continued).

.1000+04 .2521+01 .1337+01 .1507+03 -.1166+01 .6541+00

Y A5B

1	1	.3086419753-004	.1516107908-042
2	1	.0000000000	.0000000000
3	1	-.3086419753-004	-.1516107908-042
4	1	.0000000000	.0000000000
5	1	.0000000000	.0000000000
1	2	.0000000000	.0000000000
2	2	-.1336419753-001	-.3738495262-005
3	2	-.3086419753-004	-.1516107908-042
4	2	.0000000000	-.3738495262-005
5	2	.0000000000	.0000000000
1	3	-.3086419753-004	-.1516107908-042
2	3	.3086419753-004	.1516107908-042
3	3	.9259259259-004	.3733627602-004
4	3	-.3086419753-004	-.1516107908-042
5	3	.0000000000	.0000000000
1	4	.0000000000	.0000000000
2	4	-.9020370072-001	.9332426110+001
3	4	-.3086419753-004	-.1516107908-042
4	4	.3286419753-004	.3747291721-005
5	4	-.1000000000-005	-.4396229723-008
1	5	.0000000000	.0000000000
2	5	.9020370072-001	-.9332422371+001
3	5	.0000000000	.0000000000
4	5	-.1000000000-005	-.4396229723-008
5	5	.1000000004+011	.6327167579-006

Y A2B

1	1	.2590981634-004	.7615798017-005
2	1	.2113810541+001	.1185118564+001
1	2	-.5805664044-005	.6549274366-005
2	2	.9452805601+000	.1547028052+001

A A2B

1	1	-.6524349981+000	-.3660759603+000
2	1	-.2014182002-004	-.7513038699-005
1	2	.3599383888+000	-.2016012770+000
2	2	.1074173455-004	-.2703378989-005

Figure F.7. (Continued).

.1000+04 -.5080+01 .5572+00 .7395+02 .1258+00 .5428+00

Y A5B

1	1	.3086419753-004	.1516107908-042
2	1	.0000000000	.0000000000
3	1	-.3086419753-004	-.1516107908-042
4	1	.0000000000	.0000000000
5	1	.0000000000	.0000000000
1	2	.0000000000	.0000000000
2	2	-.1336419753-001	-.1797619312-004
3	2	-.3086419753-004	-.1516107908-042
4	2	.0000000000	-.1797619312-004
5	2	.0000000000	.0000000000
1	3	-.3086419753-004	-.1516107908-042
2	3	.3086419753-004	.1516107908-042
3	3	.9259259259-004	.7414158648-004
4	3	-.3086419753-004	-.1516107908-042
5	3	.0000000000	.0000000000
1	4	.0000000000	.0000000000
2	4	-.9020370072-001	.9332440347+001
3	4	-.3086419753-004	-.1516107908-042
4	4	.3286419753-004	.1796498958-004
5	4	-.1000000000-005	-.4398229723-008
1	5	.0000000000	.0000000000
2	5	.9020370072-001	-.9332422371+001
3	5	.0000000000	.0000000000
4	5	-.1000000000-005	-.4398229723-008
5	5	.1000000004+011	.6327167579-006

Y A2B

1	1	.2546297145-004	.6635480913-005
2	1	.2092203102+001	.4070296641+000
1	2	-.9436436353-005	.3890467671-005
2	2	-.1559567494+001	.3493203240+001

A A2B

1	1	.4052606604+000	-.1748466776+001
2	1	.1248262034-004	-.3594159251-004
1	2	.4605336714+000	-.3959475180-001
2	2	.1232105999-004	.7745137787-006

Figure F.7. (Continued).

.1000+04	-.8185+02	.8085-04	-.1762+03	-.8068-04	-.5318-05

A A2A

1	1	-.1234127686+005	.8134926955+003
2	1	-.5412253636-001	-.4034435188+000
1	2	-.1509331443+004	-.2859075627+004
2	2	.9053119877-001	-.5591187619-001

F	DB	MAG	ANG DEG	REAL	IMAG
.1100+04	-.3269+02	.2320-01	-.1309+02	.2260-01	-.5252-02
.1100+04	-.1986+02	.1016+00	-.1204+02	.9937-01	-.2119-01
.1100+04	-.1246+02	.2382+00	-.9079+01	.2352+00	-.3758-01
.1100+04	-.9311+01	.3423+00	-.3677+01	.3416+00	-.2196-01
.1100+04	.1377+01	.1172+01	.1779+03	-.1171+01	.4347-01
.1100+04	.1909+01	.1246+01	.1705+03	-.1229+01	.2052+00
.1100+04	.3029+01	.1417+01	.1452+03	-.1164+01	.8087+00
.1100+04	-.6220+01	.4887+00	.6999+02	.1672+00	.4591+00
.1100+04	-.7423+02	.1944-03	.1657+03	-.1883-03	.4796-04
F	DB	MAG	ANG DEG	REAL	IMAG
.1200+04	-.3118+02	.2760-01	-.1429+02	.2674-01	-.6813-02
.1200+04	-.1822+02	.1228+00	-.1335+02	.1195+00	-.2835-01
.1200+04	-.1056+02	.2965+00	-.1036+02	.2917+00	-.5333-01
.1200+04	-.7155+01	.4388+00	-.4306+01	.4376+00	-.3295-01
.1200+04	.1665+01	.1211+01	.1776+03	-.1210+01	.5062-01
.1200+04	.2317+01	.1306+01	.1692+03	-.1282+01	.2458+00
.1200+04	.3543+01	.1504+01	.1367+03	-.1129+01	.9927+00
.1200+04	-.7360+01	.4285+00	.6398+02	.1880+00	.3851+00
.1200+04	-.6695+02	.4494-03	.1471+03	-.3774-03	.2440-03
F	DB	MAG	ANG DEG	REAL	IMAG
.1300+04	-.2980+02	.3237-01	-.1550+02	.3120-01	-.8653-02
.1300+04	-.1668+02	.1465+00	-.1473+02	.1417+00	-.3727-01
.1300+04	-.8727+01	.3661+00	-.1182+02	.3584+00	-.7500-01
.1300+04	-.5006+01	.5619+00	-.5073+01	.5597+00	-.4969-01
.1300+04	.1989+01	.1257+01	.1773+03	-.1256+01	.5900-01
.1300+04	.2780+01	.1377+01	.1676+03	-.1345+01	.2960+00
.1300+04	.4020+01	.1589+01	.1310+03	-.1041+01	.1200+01
.1300+04	-.8481+01	.3767+00	.5881+02	.1951+00	.3222+00
.1300+04	-.5990+02	.1012-02	.1275+03	-.6162-03	.8022-03
F	DB	MAG	ANG DEG	REAL	IMAG
.1400+04	-.2851+02	.3752-01	-.1672+02	.3594-01	-.1079-01
.1400+04	-.1524+02	.1731+00	-.1619+02	.1662+00	-.4825-01
.1400+04	-.6940+01	.4498+00	-.1350+02	.4374+00	-.1050+00
.1400+04	-.2820+01	.7228+00	-.6037+01	.7188+00	-.7602-01
.1400+04	.2354+01	.1311+01	.1770+03	-.1309+01	.6900-01
.1400+04	.3304+01	.1463+01	.1658+03	-.1418+01	.3595+00
.1400+04	.4394+01	.1658+01	.1219+03	-.8767+00	.1408+01
.1400+04	-.9570+01	.3323+00	.5434+02	.1937+00	.2700+00
.1400+04	-.5302+02	.2232-02	.1066+03	-.6366-03	.2140-02
F	DB	MAG	ANG DEG	REAL	IMAG
.1500+04	-.2732+02	.4305-01	-.1794+02	.4096-01	-.1326-01
.1500+04	-.1387+02	.2026+00	-.1773+02	.1930+00	-.6169-01
.1500+04	-.5178+01	.5510+00	-.1546+02	.5310+00	-.1469+00
.1500+04	-.5421+00	.9395+00	-.7297+01	.9319+00	-.1193+00
.1500+04	.2763+01	.1374+01	.1766+03	-.1372+01	.8119-01
.1500+04	.3896+01	.1566+01	.1636+03	-.1503+01	.4411+00
.1500+04	.4584+01	.1695+01	.1117+03	-.6263+00	.1575+01

Figure F.7. (Continued).

.1500+04	-.1062+02	.2945+00	.5546+02	.1875+00	.2271+00
.1500+04	-.4628+02	.4653-02	.6397+02	.5095-03	.4326-02
F	DB	MAG	ANG DEG	REAL	IMAG
.1600+04	-.2621+02	.4695-01	-.1916+02	.4624-01	-.1607-01
.1600+04	-.1256+02	.2354+00	-.1936+02	.2221+00	-.7806-01
.1600+04	-.3421+01	.6745+00	-.1779+02	.6422+00	-.2060+00
.1600+04	.1697+01	.1244+01	-.9028+01	.1229+01	-.1952+00
.1600+04	.3222+01	.1449+01	.1762+03	-.1446+01	.9598-01
.1600+04	.4564+01	.1691+01	.1611+03	-.1600+01	.5484+00
.1600+04	.4513+01	.1681+01	.1007+03	-.3115+00	.1652+01
.1600+04	-.1163+02	.2622+00	.4767+02	.1786+00	.1920+00
.1600+04	-.3962+02	.1045-01	.5968+02	.5276-02	.9022-02
F	DB	MAG	ANG DEG	REAL	IMAG
.1700+04	-.2516+02	.5521-01	-.2040+02	.5175-01	-.1924-01
.1700+04	-.1132+02	.2718+00	-.2111+02	.2535+00	-.9788-01
.1700+04	-.1651+01	.8269+00	-.2061+02	.7739+00	-.2911+00
.1700+04	.4602+01	.1699+01	-.1157+02	.1664+01	-.3407+00
.1700+04	.3739+01	.1538+01	.1757+03	-.1534+01	.1147+00
.1700+04	.5316+01	.1844+01	.1579+03	-.1709+01	.6925+00
.1700+04	.4142+01	.1611+01	.8958+02	.1173-01	.1611+01
.1700+04	-.1259+02	.2346+00	.4409+02	.1685+00	.1633+00
.1700+04	-.3291+02	.2261-01	.3365+02	.1882-01	.1253-01
F	DB	MAG	ANG DEG	REAL	IMAG
.1800+04	-.2417+02	.6185-01	-.2163+02	.5749-01	-.2280-01
.1800+04	-.1012+02	.3120+00	-.2297+02	.2873+00	-.1218+00
.1800+04	.1472+00	.1017+01	-.2410+02	.9284+00	-.4153+00
.1800+04	.7742+01	.2438+01	-.1569+02	.2347+01	-.6595+00
.1800+04	.4322+01	.1645+01	.1752+03	-.1639+01	.1386+00
.1800+04	.6161+01	.2033+01	.1540+03	-.1827+01	.8900+00
.1800+04	.3492+01	.1495+01	.7913+02	.2820+00	.1468+01
.1800+04	-.1352+02	.2109+00	.4146+02	.1581+00	.1397+00
.1800+04	-.2593+02	.5050-01	.5378+01	.5027-01	.4733-02
F	DB	MAG	ANG DEG	REAL	IMAG
.1900+04	-.2324+02	.6884-01	-.2287+02	.6343-01	-.2676-01
.1900+04	-.8959+01	.3565+00	-.2498+02	.3231+00	-.1505+00
.1900+04	.1987+01	.1257+01	-.2851+02	.1105+01	-.6001+00
.1900+04	.1162+02	.3809+01	-.2345+02	.3494+01	-.1516+01
.1900+04	.4983+01	.1775+01	.1745+03	-.1767+01	.1700+00
.1900+04	.7100+01	.2265+01	.1490+03	-.1942+01	.1165+01
.1900+04	.2634+01	.1354+01	.6962+02	.4673+00	.1271+01
.1900+04	-.1440+02	.1905+00	.3912+02	.1478+00	.1202+00
.1900+04	-.1827+02	.1220+00	-.2737+02	.1083+00	-.5608-01
F	DB	MAG	ANG DEG	REAL	IMAG
.2000+04	-.2236+02	.7620-01	-.2412+02	.6955-01	-.3114-01
.2000+04	-.7640+01	.4055+00	-.2713+02	.3609+00	-.1849+00
.2000+04	.3870+01	.1561+01	-.3422+02	.1291+01	-.8780+00
.2000+04	.1664+02	.6789+01	-.4203+02	.5043+01	-.4545+01
.2000+04	.5739+01	.1936+01	.1737+03	-.1924+01	.2125+00
.2000+04	.8121+01	.2547+01	.1425+03	-.2021+01	.1550+01
.2000+04	.1649+01	.1209+01	.6164+02	.5706+00	.1066+01
.2000+04	-.1525+02	.1726+00	.3702+02	.1380+00	.1040+00
.2000+04	-.9422+01	.3380+00	-.7251+02	.1016+00	-.3224+00
F	DB	MAG	ANG DEG	REAL	IMAG
.2100+04	-.2152+02	.8391-01	-.2538+02	.7582-01	-.3596-01
.2100+04	-.6755+01	.4594+00	-.2946+02	.4000+00	-.2260+00
.2100+04	.5774+01	.1944+01	-.4174+02	.1451+01	-.1294+01
.2100+04	.2059+02	.1071+02	-.9227+02	-.4244+00	-.1070+02

Figure F.7. (Continued).

.2100+04	.6608+01	.2140+01	.1727+03	-.2123+01	.2719+00
.2100+04	.9175+01	.2876+01	.1339+03	-.1993+01	.2074+01
.2100+04	.6074+00	.1072+01	.5515+02	.6129+00	.8801+00
.2100+04	-.1606+02	.1574+00	.3513+02	.1287+00	.9056-01
.2100+04	-.1576+01	.8339+00	-.1522+03	-.7374+00	-.3893+00
F	DB	MAG	ANG DEG	REAL	IMAG
.2200+04	-.2073+02	.9198-01	-.2664+02	.8221-01	-.4124-01
.2200+04	-.5703+01	.5186+00	-.3199+02	.4399+00	-.2747+00
.2200+04	.7625+01	.2406+01	-.5173+02	.1490+01	-.1889+01
.2200+04	.1740+02	.7417+01	-.1390+03	-.5598+01	-.4866+01
.2200+04	.7622+01	.2405+01	.1714+03	-.2378+01	.3588+00
.2200+04	.1014+02	.3215+01	.1225+03	-.1725+01	.2713+01
.2200+04	-.4432+00	.9502+00	.4958+02	.6161+00	.7234+00
.2200+04	-.1684+02	.1439+00	.3343+02	.1201+00	.7925-01
.2200+04	-.9233+00	.8992+00	.1275+03	-.5469+00	.7137+00
F	DB	MAG	ANG DEG	REAL	IMAG
.2300+04	-.1997+02	.1004+00	-.2790+02	.8871-01	-.4698-01
.2300+04	-.4680+01	.5834+00	-.3472+02	.4795+00	-.3323+00
.2300+04	.9254+01	.2902+01	-.6471+02	.1240+01	-.2624+01
.2300+04	.1375+02	.4872+01	-.1553+03	-.4445+01	-.1993+01
.2300+04	.8820+01	.2760+01	.1697+03	-.2716+01	.4931+00
.2300+04	.1080+02	.3468+01	.1081+03	-.1076+01	.3297+01
.2300+04	-.1474+01	.8439+00	.4494+02	.5973+00	.5961+00
.2300+04	-.1759+02	.1320+00	.3188+02	.1121+00	.6971-01
.2300+04	-.1082+01	.8829+00	.7139+02	.2817+00	.8367+00
F	DB	MAG	ANG DEG	REAL	IMAG
.2400+04	-.1924+02	.1091+00	-.2918+02	.9529-01	-.5320-01
.2400+04	-.3689+01	.6540+00	-.3770+02	.5174+00	-.3999+00
.2400+04	.1039+02	.3309+01	-.8039+02	.5521+00	-.3262+01
.2400+04	.1124+02	.3646+01	-.1631+03	-.3488+01	-.1062+01
.2400+04	.1026+02	.3260+01	.1673+03	-.3181+01	.7157+00
.2400+04	.1088+02	.3498+01	.9171+02	-.1044+00	.3496+01
.2400+04	-.2470+01	.7525+00	.4106+02	.5674+00	.4942+00
.2400+04	-.1831+02	.1215+00	.3047+02	.1047+00	.6160-01
.2400+04	-.9345+00	.8980+00	.2019+02	.8428+00	.3100+00
F	DB	MAG	ANG DEG	REAL	IMAG
.2500+04	-.1855+02	.1182+00	-.3046+02	.1019+00	-.5992-01
.2500+04	-.2730+01	.7303+00	-.4093+02	.5517+00	-.4785+00
.2500+04	.1082+02	.3477+01	-.9698+02	-.4224+00	-.3451+01
.2500+04	.9440+01	.2965+01	-.1670+03	-.2889+01	-.6685+00
.2500+04	.1205+02	.4006+01	.1637+03	-.3845+01	.1122+01
.2500+04	.1026+02	.3258+01	.7570+02	.8049+00	.3157+01
.2500+04	-.3425+01	.6742+00	.3778+02	.5329+00	.4130+00
.2500+04	-.1900+02	.1122+00	.2917+02	.9796-01	.5468-01
.2500+04	-.1117+01	.8793+00	-.2699+02	.7691+00	-.4262+00
F	DB	MAG	ANG DEG	REAL	IMAG
.2600+04	-.1788+02	.1276+00	-.3174+02	.1085+00	-.6714-01
.2600+04	-.1806+01	.8123+00	-.4445+02	.5799+00	-.5688+00
.2600+04	.1059+02	.3385+01	-.1120+03	-.1268+01	-.3138+01
.2600+04	.8088+01	.2538+01	-.1694+03	-.2494+01	-.4669+00
.2600+04	.1434+02	.5213+01	.1578+03	-.4826+01	.1971+01
.2600+04	.9129+01	.2860+01	.6210+02	.1339+01	.2528+01
.2600+04	-.4335+01	.6071+00	.3498+02	.4974+00	.3480+00
.2600+04	-.1967+02	.1039+00	.2798+02	.9175-01	.4875-01
.2600+04	-.1530+01	.8385+00	-.7478+02	.2201+00	-.8091+00
F	DB	MAG	ANG DEG	REAL	IMAG
.2700+04	-.1724+02	.1373+00	-.3304+02	.1151+00	-.7488-01

Figure F.7. (Continued).

.2700+04	-.9203+00	.8995+00	-.4826+02	.5989+00	-.6711+00
.2700+04	.9957+01	.3147+01	-.1241+03	-.1764+01	-.2606+01
.2700+04	.7031+01	.2247+01	-.1711+03	-.2219+01	-.3493+00
.2700+04	.1734+02	.7366+01	.1464+03	-.6136+01	.4074+01
.2700+04	.7756+01	.2442+01	.5151+02	.1520+01	.1912+01
.2700+04	-.5203+01	.5494+00	.3257+02	.4630+00	.2958+00
.2700+04	-.2031+02	.9648-01	.2608+02	.8606-01	.4363-01
.2700+04	-.1573+01	.8343+00	-.1191+03	-.4060+00	-.7288+00
F	DB	MAG	ANG DEG	REAL	IMAG
.2800+04	-.1663+02	.1474+00	-.3433+02	.1217+00	-.8313-01
.2800+04	-.7985-01	.9908+00	-.5237+02	.6049+00	-.7848+00
.2800+04	.9172+01	.2875+01	-.1333+03	-.1971+01	-.2093+01
.2800+04	.6179+01	.2037+01	-.1723+03	-.2018+01	-.2742+00
.2800+04	.2088+02	.1107+02	.1208+03	-.5660+01	.9514+01
.2800+04	.6338+01	.2074+01	.4353+02	.1504+01	.1429+01
.2800+04	-.6028+01	.4995+00	.3048+02	.4305+00	.2534+00
.2800+04	-.2093+02	.8983-01	.2587+02	.8083-01	.3919-01
.2800+04	-.1079+01	.8831+00	-.1718+03	-.8741+00	-.1261+00
F	DB	MAG	ANG DEG	REAL	IMAG
.2900+04	-.1604+02	.1577+00	-.3564+02	.1282+00	-.9190-01
.2900+04	.7086+00	.1085+01	-.5680+02	.5941+00	-.9079+00
.2900+04	.8381+01	.2625+01	-.1402+03	-.2016+01	-.1680+01
.2900+04	.5476+01	.1678+01	-.1732+03	-.1865+01	-.2230+00
.2900+04	.2157+02	.1199+02	.7388+02	.3328+01	.1152+02
.2900+04	.4971+01	.1772+01	.3750+02	.1406+01	.1079+01
.2900+04	-.6815+01	.4563+00	.2865+02	.4004+00	.2188+00
.2900+04	-.2153+02	.8383-01	.2492+02	.7602-01	.3533-01
.2900+04	-.3280+01	.6855+00	.1189+03	-.3312+00	.6002+00
F	DB	MAG	ANG DEG	REAL	IMAG
.3000+04	-.1548+02	.1684+00	-.3695+02	.1345+00	-.1012+00
.3000+04	.1437+01	.1180+01	-.6151+02	.5628+00	-.1037+01
.3000+04	.7644+01	.2411+01	-.1455+03	-.1986+01	-.1367+01
.3000+04	.4886+01	.1755+01	-.1739+03	-.1745+01	-.1863+00
.3000+04	.1800+02	.7946+01	.4103+02	.5994+01	.5216+01
.3000+04	.3690+01	.1529+01	.3287+02	.1285+01	.8300+00
.3000+04	-.7566+01	.4185+00	.2704+02	.3727+00	.1903+00
.3000+04	-.2211+02	.7841-01	.2405+02	.7160-01	.3195-01
.3000+04	-.9508+01	.3346+00	.6701+02	.1307+00	.3081+00
F	DB	MAG	ANG DEG	REAL	IMAG
.3100+04	-.1493+02	.1793+00	-.3827+02	.1407+00	-.1110+00
.3100+04	.2097+01	.1273+01	-.6649+02	.5078+00	-.1167+01
.3100+04	.6981+01	.2234+01	-.1495+03	-.1925+01	-.1133+01
.3100+04	.4385+01	.1657+01	-.1745+03	-.1649+01	-.1589+00
.3100+04	.1446+02	.5281+01	.2670+02	.4718+01	.2373+01
.3100+04	.2502+01	.1334+01	.2924+02	.1164+01	.6516+00
.3100+04	-.8283+01	.3853+00	.2561+02	.3475+00	.1665+00
.3100+04	-.2268+02	.7349-01	.2323+02	.6753-01	.2898-01
.3100+04	-.1548+02	.1682+00	.3569+02	.1363+00	.9862-01
F	DB	MAG	ANG DEG	REAL	IMAG
.3200+04	-.1440+02	.1904+00	-.3959+02	.1468+00	-.1214+00
.3200+04	.2681+01	.1362+01	-.7169+02	.4279+00	-.1293+01
.3200+04	.6390+01	.2087+01	-.1528+03	-.1856+01	-.9553+00
.3200+04	.3952+01	.1576+01	-.1750+03	-.1570+01	-.1378+00
.3200+04	.1167+02	.3833+01	.1959+02	.3611+01	.1285+01
.3200+04	.1402+01	.1175+01	.2634+02	.1053+01	.5214+00
.3200+04	-.8970+01	.3561+00	.2432+02	.3244+00	.1466+00
.3200+04	-.2322+02	.6902-01	.2246+02	.6378-01	.2637-01

Figure F.7. (Continued).

F	DB	MAG	ANG DEG	REAL	IMAG
.3200+04	-.2051+02	.9430-01	.1363+02	.9164-01	.2222-01
F	DB	MAG	ANG DEG	REAL	IMAG
.3300+04	-.1390+02	.2019+00	-.4092+02	.1526+00	-.1322+00
.3300+04	.3183+01	.1443+01	-.7703+02	.3239+00	-.1406+01
.3300+04	.5868+01	.1965+01	-.1554+03	-.1786+01	-.8191+00
.3300+04	.3576+01	.1509+01	-.1754+03	-.1505+01	-.1211+00
.3300+04	.9445+01	.2967+01	.1547+02	.2859+01	.7910+00
.3300+04	.3812+00	.1045+01	.2397+02	.9547+00	.4245+00
.3300+04	-.9628+01	.3301+00	.2317+02	.3035+00	.1299+00
.3300+04	-.2375+02	.6494-01	.2174+02	.6032-01	.2406-01
.3300+04	-.2483+02	.5734-01	-.4419+01	.5717-01	-.4418-02
F	DB	MAG	ANG DEG	REAL	IMAG
.3400+04	-.1341+02	.2136+00	-.4225+02	.1581+00	-.1436+00
.3400+04	.3599+01	.1513+01	-.8243+02	.1993+00	-.1500+01
.3400+04	.5404+01	.1863+01	-.1575+03	-.1721+01	-.7125+00
.3400+04	.3246+01	.1453+01	-.1758+03	-.1449+01	-.1077+00
.3400+04	.7603+01	.2400+01	.1279+02	.2340+01	.5312+00
.3400+04	-.5684+00	.9367+00	.2201+02	.8684+00	.3510+00
.3400+04	-.1026+02	.3069+00	.2212+02	.2843+00	.1156+00
.3400+04	-.2426+02	.6121-01	.2107+02	.5712-01	.2200-01
.3400+04	-.2866+02	.3692-01	-.2002+02	.3469-01	-.1264-01
F	DB	MAG	ANG DEG	REAL	IMAG
.3500+04	-.1294+02	.2255+00	-.4359+02	.1633+00	-.1555+00
.3500+04	.3928+01	.1572+01	-.8782+02	.5978-01	-.1571+01
.3500+04	.4993+01	.1777+01	-.1593+03	-.1662+01	-.6277+00
.3500+04	.2955+01	.1405+01	-.1761+03	-.1402+01	-.9656-01
.3500+04	.6031+01	.2002+01	.1092+02	.1966+01	.3792+00
.3500+04	-.1456+01	.8457+00	.2035+02	.7929+00	.2941+00
.3500+04	-.1087+02	.2862+00	.2117+02	.2669+00	.1034+00
.3500+04	-.2476+02	.5780-01	.2043+02	.5416-01	.2018-01
.3500+04	-.3212+02	.2477-01	-.3395+02	.2055-01	-.1384-01
F	DB	MAG	ANG DEG	REAL	IMAG
.3600+04	-.1248+02	.2376+00	-.4493+02	.1682+00	-.1678+00
.3600+04	.4174+01	.1617+01	-.9310+02	-.8747-01	-.1615+01
.3600+04	.4626+01	.1703+01	-.1608+03	-.1609+01	-.5591+00
.3600+04	.2695+01	.1364+01	-.1763+03	-.1361+01	-.8727-01
.3600+04	.4660+01	.1710+01	.9534+01	.1686+01	.2832+00
.3600+04	-.2287+01	.7685+00	.1894+02	.7269+00	.2494+00
.3600+04	-.1145+02	.2676+00	.2030+02	.2510+00	.9285-01
.3600+04	-.2525+02	.5465-01	.1963+02	.5141-01	.1854-01
.3600+04	-.3532+02	.1714-01	-.4663+02	.1177-01	-.1246-01
F	DB	MAG	ANG DEG	REAL	IMAG
.3700+04	-.1204+02	.2500+00	-.4627+02	.1728+00	-.1806+00
.3700+04	.4344+01	.1649+01	-.9820+02	-.2352+00	-.1632+01
.3700+04	.4297+01	.1640+01	-.1621+03	-.1561+01	-.5023+00
.3700+04	.2463+01	.1328+01	-.1766+03	-.1325+01	-.7939-01
.3700+04	.3441+01	.1486+01	.8471+01	.1470+01	.2189+00
.3700+04	-.3071+01	.7022+00	.1772+02	.6689+00	.2137+00
.3700+04	-.1201+02	.2508+00	.1950+02	.2364+00	.8373-01
.3700+04	-.2572+02	.5176-01	.1927+02	.4886-01	.1708-01
.3700+04	-.3831+02	.1215-01	-.5827+02	.6391-02	-.1034-01
F	DB	MAG	ANG DEG	REAL	IMAG
.3800+04	-.1162+02	.2625+00	-.4762+02	.1769+00	-.1939+00
.3800+04	.4446+01	.1668+01	-.1031+03	-.3769+00	-.1625+01
.3800+04	.4002+01	.1585+01	-.1633+03	-.1518+01	-.4559+00
.3800+04	.2254+01	.1296+01	-.1768+03	-.1294+01	-.7262-01
.3800+04	.2343+01	.1310+01	.7628+01	.1298+01	.1738+00

Figure F.7. (Continued).

.3800+04	-.3810+01	.6449+00	.1666+02	.6178+00	.1849+00
.3800+04	-.1256+02	.2356+00	.1677+02	.2231+00	.7579-01
.3800+04	-.2618+02	.4909-01	.1873+02	.4649-01	.1576-01
.3800+04	-.4112+02	.8787-02	-.6901+02	.3147-02	-.8204-02
F	DB	MAG	ANG DEG	REAL	IMAG
.3900+04	-.1121+02	.2752+00	-.4898+02	.1806+00	-.2076+00
.3900+04	.4491+01	.1677+01	-.1076+03	-.5079+00	-.1598+01
.3900+04	.3736+01	.1537+01	-.1643+03	-.1480+01	-.4164+00
.3900+04	.2066+01	.1268+01	-.1770+03	-.1267+01	-.6675-01
.3900+04	.1343+01	.1167+01	.6941+01	.1159+01	.1411+00
.3900+04	-.4511+01	.5949+00	.1572+02	.5726+00	.1612+00
.3900+04	-.1308+02	.2217+00	.1809+02	.2108+00	.6885-01
.3900+04	-.2663+02	.4662-01	.1822+02	.4428-01	.1458-01
.3900+04	-.4380+02	.6457-02	-.7894+02	.1238-02	-.6337-02
F	DB	MAG	ANG DEG	REAL	IMAG
.4000+04	-.1081+02	.2880+00	-.5033+02	.1839+00	-.2217+00
.4000+04	.4487+01	.1676+01	-.1119+03	-.6251+00	-.1555+01
.4000+04	.3494+01	.1495+01	-.1652+03	-.1445+01	-.3827+00
.4000+04	.1894+01	.1244+01	-.1772+03	-.1242+01	-.6160-01
.4000+04	.4231+00	.1050+01	.6371+01	.1043+01	.1165+00
.4000+04	-.5178+01	.5510+00	.1489+02	.5325+00	.1416+00
.4000+04	-.1359+02	.2091+00	.1746+02	.1995+00	.6274-01
.4000+04	-.2707+02	.4433-01	.1774+02	.4223-01	.1351-01
.4000+04	-.4635+02	.4814-02	-.8814+02	.1563-03	-.4811-02
F	DB	MAG	ANG DEG	REAL	IMAG
.4100+04	-.1043+02	.3010+00	-.5169+02	.1866+00	-.2362+00
.4100+04	.4446+01	.1668+01	-.1158+03	-.7272+00	-.1502+01
.4100+04	.3275+01	.1458+01	-.1660+03	-.1414+01	-.3538+00
.4100+04	.1739+01	.1222+01	-.1773+03	-.1220+01	-.5705-01
.4100+04	-.4293+00	.9518+00	.5889+01	.9468+00	.9765-01
.4100+04	-.5813+01	.5121+00	.1415+02	.4966+00	.1252+00
.4100+04	-.1408+02	.1976+00	.1687+02	.1891+00	.5735-01
.4100+04	-.2749+02	.4221-01	.1728+02	.4031-01	.1254-01
.4100+04	-.4879+02	.3635-02	-.9667+02	-.4220-03	-.3611-02
F	DB	MAG	ANG DEG	REAL	IMAG
.4200+04	-.1006+02	.3141+00	-.5305+02	.1888+00	-.2510+00
.4200+04	.4376+01	.1655+01	-.1195+03	-.8144+00	-.1441+01
.4200+04	.3075+01	.1425+01	-.1667+03	-.1386+01	-.3286+00
.4200+04	.1596+01	.1202+01	-.1775+03	-.1201+01	-.5299-01
.4200+04	-.1224+01	.8685+00	.5476+01	.8646+00	.8289-01
.4200+04	-.6420+01	.4775+00	.1348+02	.4644+00	.1113+00
.4200+04	-.1456+02	.1870+00	.1632+02	.1795+00	.5256-01
.4200+04	-.2791+02	.4024-01	.1684+02	.3851-01	.1166-01
.4200+04	-.5113+02	.2777-02	-.1046+03	-.6994-03	-.2688-02
F	DB	MAG	ANG DEG	REAL	IMAG
.4300+04	-.9701+01	.3273+00	-.5441+02	.1905+00	-.2662+00
.4300+04	.4284+01	.1638+01	-.1228+03	-.8875+00	-.1376+01
.4300+04	.2892+01	.1395+01	-.1673+03	-.1361+01	-.3066+00
.4300+04	.1466+01	.1184+01	-.1776+03	-.1183+01	-.4935-01
.4300+04	-.1970+01	.7971+00	.5118+01	.7939+00	.7110-01
.4300+04	-.7001+01	.4466+00	.1287+02	.4354+00	.9949-01
.4300+04	-.1503+02	.1773+00	.1581+02	.1706+00	.4831-01
.4300+04	-.2831+02	.3839-01	.1643+02	.3683-01	.1086-01
.4300+04	-.5337+02	.2145-02	-.1120+03	-.8019-03	-.1989-02
F	DB	MAG	ANG DEG	REAL	IMAG
.4400+04	-.9355+01	.3406+00	-.5577+02	.1916+00	-.2816+00
.4400+04	.4177+01	.1616+01	-.1259+03	-.9479+00	-.1311+01

Figure F.7. (Continued).

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.4400+04	.2724+01	.1368+01	-.1679+03	-.1338+01	-.2872+00
.4400+04	.1346+01	.1168+01	-.1777+03	-.1167+01	-.4606-01
.4400+04	-.2672+01	.7352+00	.4804+01	.7326+00	.6157-01
.4400+04	-.7559+01	.4189+00	.1292+02	.4092+00	.0938-01
.4400+04	-.1546+02	.1683+00	.1533+02	.1623+00	.4450-01
.4400+04	-.2871+02	.3666-01	.1603+02	.3525-01	.1013-01
.4400+04	-.5553+02	.1673-02	-.1188+03	-.8067-03	-.1466-02
F	DB	MAG	ANG DEG	REAL	IMAG
.4500+04	-.9021+01	.3539+00	-.5712+02	.1921+00	-.2973+00
.4500+04	.4060+01	.1596+01	-.1287+03	-.9972+00	-.1246+01
.4500+04	.2570+01	.1344+01	-.1684+03	-.1317+01	-.2699+00
.4500+04	.1235+01	.1153+01	-.1779+03	-.1152+01	-.4307-01
.4500+04	-.3336+01	.6811+00	.4525+01	.6790+00	.5374-01
.4500+04	-.8095+01	.3938+00	.1182+02	.3854+00	.8064-01
.4500+04	-.1591+02	.1600+00	.1488+02	.1547+00	.4110-01
.4500+04	-.2910+02	.3507-01	.1565+02	.3377-01	.9463-02
.4500+04	-.5760+02	.1318-02	-.1252+03	-.7603-03	-.1076-02
F	DB	MAG	ANG DEG	REAL	IMAG
.4600+04	-.8698+01	.3674+00	-.5848+02	.1920+00	-.3132+00
.4600+04	.3937+01	.1573+01	-.1312+03	-.1037+01	-.1183+01
.4600+04	.2427+01	.1322+01	-.1689+03	-.1298+01	-.2545+00
.4600+04	.1133+01	.1139+01	-.1780+03	-.1139+01	-.4034-01
.4600+04	-.3966+01	.6334+00	.4277+01	.6316+00	.4724-01
.4600+04	-.8611+01	.3711+00	.1135+02	.3638+00	.7305-01
.4600+04	-.1634+02	.1524+00	.1445+02	.1476+00	.3803-01
.4600+04	-.2948+02	.3357-01	.1529+02	.3238-01	.8853-02
.4600+04	-.5960+02	.1047-02	-.1313+03	-.6903-03	-.7869-03
F	DB	MAG	ANG DEG	REAL	IMAG
.4700+04	-.8387+01	.3808+00	-.5984+02	.1913+00	-.3292+00
.4700+04	.3810+01	.1551+01	-.1336+03	-.1069+01	-.1123+01
.4700+04	.2296+01	.1302+01	-.1694+03	-.1280+01	-.2406+00
.4700+04	.1038+01	.1127+01	-.1781+03	-.1126+01	-.3784-01
.4700+04	-.4567+01	.5911+00	.4054+01	.5896+00	.4179-01
.4700+04	-.9109+01	.3504+00	.1093+02	.3440+00	.6642-01
.4700+04	-.1676+02	.1453+00	.1405+02	.1409+00	.3527-01
.4700+04	-.2985+02	.3216-01	.1494+02	.3108-01	.8294-02
.4700+04	-.6153+02	.8385-03	-.1369+03	-.6124-03	-.5728-03
F	DB	MAG	ANG DEG	REAL	IMAG
.4800+04	-.8085+01	.3942+00	-.6119+02	.1900+00	-.3454+00
.4800+04	.3682+01	.1528+01	-.1357+03	-.1094+01	-.1067+01
.4800+04	.2173+01	.1284+01	-.1698+03	-.1264+01	-.2281+00
.4800+04	.9500+00	.1116+01	-.1782+03	-.1115+01	-.3553-01
.4800+04	-.5140+01	.5534+00	.3853+01	.5521+00	.3719-01
.4800+04	-.9591+01	.3315+00	.1053+02	.3259+00	.6060-01
.4800+04	-.1716+02	.1386+00	.1367+02	.1347+00	.3277-01
.4800+04	-.3022+02	.3084-01	.1461+02	.2984-01	.7780-02
.4800+04	-.6339+02	.6769-03	-.1422+03	-.5351-03	-.4145-03
F	DB	MAG	ANG DEG	REAL	IMAG
.4900+04	-.7794+01	.4076+00	-.6254+02	.1880+00	-.3617+00
.4900+04	.3555+01	.1506+01	-.1377+03	-.1114+01	-.1013+01
.4900+04	.2060+01	.1268+01	-.1702+03	-.1249+01	-.2168+00
.4900+04	.8682+00	.1105+01	-.1783+03	-.1105+01	-.3339-01
.4900+04	-.5689+01	.5195+00	.3669+01	.5184+00	.3325-01
.4900+04	-.1006+02	.3142+00	.1017+02	.3093+00	.5546-01
.4900+04	-.1756+02	.1325+00	.1331+02	.1289+00	.3050-01
.4900+04	-.3057+02	.2960-01	.1429+02	.2868-01	.7307-02
.4900+04	-.6519+02	.5503-03	-.1473+03	-.4630-03	-.2975-03

Figure F.7. (Continued).

F	DB	MAG	ANG DEG	REAL	IMAG
.5000+04	-.7513+01	.4211+00	-.6389+02	.1853+00	-.3781+00
.5000+04	.3430+01	.1484+01	-.1395+03	-.1129+01	-.9637+00
.5000+04	.1955+01	.1252+01	-.1705+03	-.1235+01	-.2064+00
.5000+04	.7919+00	.1095+01	-.1784+03	-.1095+01	-.3140-01
.5000+04	-.6215+01	.4889+00	.3502+01	.4880+00	.2986-01
.5000+04	-.1051+02	.2983+00	.9825+01	.2939+00	.5090-01
.5000+04	-.1794+02	.1267+00	.1297+02	.1235+00	.2844-01
.5000+04	-.3092+02	.2843-01	.1398+02	.2759-01	.6871-02
.5000+04	-.6693+02	.4505-03	-.1520+03	-.3979-03	-.2112-03

Figure F.7. (Continued).

* * * * * COMMON PRT TBL * * * * *

N	NET SP	I SIGN C	D	J PORT	N PORTS	NET NAM	NUM APO	NUM NPO	N AHEAD	N BACK	LC J ROW
1	P	1	1	1	5	AB	1	-1	3	0	1
2	P	1	1	1	2	BA	1	1	8	0	357
3	P	1	1	2	5	AB	2	-2	7	1	2
4	P	1	1	2	2	BC	2	4	13	10	447
5	P	1	1	2	2	BD	2	6	14	13	482
6	P	-1	1	3	3	BE	2	9	9	16	311
7	P	1	1	3	5	AB	3	-3	11	3	3
8	P	-1	1	2	2	BA	3	2	10	2	358
9	P	1	1	1	2	BB	3	10	12	6	411
10	P	1	1	1	2	BC	3	3	4	8	446
11	P	1	1	4	5	AB	4	-4	15	7	4
12	P	-1	1	2	2	BB	4	11	0	9	412
13	P	1	1	1	2	BD	4	5	5	4	481
14	P	1	1	1	3	BE	4	7	16	5	309
15	P	1	1	5	5	AB	5	-5	0	11	5
16	P	1	1	2	3	BE	5	8	6	14	310

* * * * * COMMON CATALG * * * * *

I	NAME	MTR SIZ	I PC	N PC TOT	I TYPE	N UT STR	LOC
1	AB	5	0	0	0	0	1
2	AA	2	0	8	0	0	101
3	AA	2	1	8	4	8	117
4	AA	2	2	8	4	8	141
5	AA	2	3	8	4	8	165
6	AA	2	4	8	4	8	189
7	AA	2	5	8	4	8	213
8	AA	2	6	8	4	8	237
9	AA	2	7	8	4	8	261
10	AA	2	8	8	4	8	285
11	BE	3	0	0	26	12	309
12	BA	2	0	2	0	0	357
13	BA	2	1	2	21	3	373
14	BA	2	2	2	22	3	392
15	BB	2	0	1	0	0	411
16	BB	2	1	1	21	3	427
17	BC	2	0	1	0	0	446
18	BC	2	1	1	21	3	462
19	BD	2	0	1	0	0	481
20	BD	2	1	1	21	3	497
21	AB	2	0	0	0	0	516
22	AB	0	0	0	0	0	532
23	AB	0	0	0	0	0	568

TOTAL DATA CELLS USED IN MASTER STORAGE 591

LAST TIME INTERVAL = 13.153 SEC   TOTAL RUN TIME = 13.153 SEC

Figure F.7. (Continued).

```
SEADUCER RUN 80117 FOR TP-22R APPENDIX F                                  DATE 102072        PAGE   36
@BRKPT   PRINT$

                    RUNID:  M80117    ACCOUNT: 1E0170010000    PROJECT: LMED10314522
                      LOAD B80117 9/5 PRFILE        -1 M80117
                      M80117*MSG: SD 2154
                      BREAKPOINT IN THIS RUN
                 *M80117  SAVE PRTAPE IS 722          C
                      LOAD 279     9/E B            -1 M80117
                      BREAKPOINT IN THIS RUN
                    TIME: 00:00:21.332    IN: 174    OUT: 46      PAGES:   44
                    WDS XFRD(E2): 555E     I/O REFS: 1954     CORE SEC: 99E
                    INITIATION  TIME:   15:22:31-OCT 20,1972      VERSION:  2E.73.198 10
                    TERMINATION TIME:   15:25:05-OCT 20,1972
```

Figure F.7. (Continued).

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13. ABSTRACT

A working guide to use of the SEADUCER (Steadystate Evaluation and Analysis of TransDUCERs) computer program is presented. SEADUCER is applied in this paper primarily to math models for longitudinal electromechanical vibrators. However, the multiport interconnection techniques used in SEADUCER are applicable to the analysis of a wide variety of transducers as well as to steady state modeling of any linear system (electrical, thermal, optical, etc.) which can be described as an M-port interconnection of N p_N-port networks.

SEADUCER has been written in ASA Standard FORTRAN so that it can easily be installed on most medium- to large-scale digital computers. The program is in use at the Naval Undersea Center and at other installations and is available to government and private organizations.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
programs (computers)						
routines (computer programming)						
sonar transducer analysis						
Multiport network interconnections						
active filter analysis						